REMEDIAL INVESTIGATION REPORT
AREA OF INTEREST 5

Sunoco Partners Marketing and Terminals LP
Marcus Hook Industrial Complex
100 Green Street, Marcus Hook Borough and Lower Chichester Township, Delaware County, Pennsylvania
Site-wide PADEP Facility ID No. 780192
Area of Interest 5 PADEP Facility ID No. 778397

Stantec

Prepared for:

Marcus Hook Refinery Operations,
a series of Evergreen Resources Group, LLC

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ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
ACGIH	American Conference of Governmental Industrial Hygienists
ANT	apparent NAPL thickness
AOC	Area of Concern
AOI	Area of Interest
AST	aboveground storage tank
C	° Celsius
CAF	Corrective Action Framework
CAP	Corrective Action Process
CCR	Current Conditions Report
CRP	Community Relations Plan
CSM	conceptual site model
COC	constituent of concern
CORMIX	Cornell Mixing Zone Expert System
DELCORA	Delaware County Regional Water Quality Control Authority
DNREC	Delaware Department of Natural Resources and Environmental Control
DVW	Delaware Valley Works
EDB	1,2-dibromoethane
EDC	1,2-dichloroethane
EPA	United States Environmental Protection Agency
Evergreen	Marcus Hook Refinery Operations, a series of Evergreen Resources Group, LLC
FOIA	Freedom of Information Act
FPL	Florida Power and Light Company
ft	feet
ft bgs	feet below ground surface
ft/d	feet per day
ft^2/day	square feet per day
ft/ft	feet per foot
GIS	graphic informational system
gpm	gallons per minute
HHRA	Human Health Risk Assessment
hp	horsepower
k	hydraulic conductivity
LDRM	LNAPL distribution and recovery modeling
LiDAR	Light Detection and Ranging
LNAPL	light non-aqueous phase liquid
LCO	light cycle oil
LCSM	LNAPL Conceptual Site Model
LPG	Liquefied Petroleum Gas
MCAP	Middle Creek Abatement Project
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/l	micrograms per liter
MHIC	Marcus Hook Industrial Complex
MSC	Medium-Specific Concentration
MTBE	methyl tert butyl ether
NAVD 88	North American Vertical Datum of 1988
NJGS	New Jersey Geological Survey
NIOSH	National Institute for Occupational Safety and Health
NIR	Notice of Intent to Remediate
NORR	Notice of Reportable Release

NOWData	National Weather Service Online Weather Data
NPDES	National Pollutant Discharge Elimination System
NRDC	non-residential direct contact
OSHA	Occupational Safety and Health Administration
PADCNR	Pennsylvania Department of Conservation and Natural Resources
PADEP	Pennsylvania Department of Environmental Protection
PAFBC	Pennsylvania Fish and Boat Commission
PaGWIS	Pennsylvania Groundwater Information System
POTW	Publicly Owned Treatment Works
PEL	Permissible Exposure Limit
PID	Photoionization Detector
PNDI	Pennsylvania Natural Diversity Inventory
PPE	Personal Protective Equipment
ppm_v	parts per million by volume
RACR	Remedial Action Completion Report
RAPR	Remedial Action Progress Reports
RCRA	Resource Conservation and Recovery Act
RCRA metals	RCRA 8 metals
REL	Recommended Exposure Limit
RFI	RCRA Facility Investigation Report
RIR	Remedial Investigation Report
RSL	Regional Screening Level
SCR	Site Characterization Report
SHS	Statewide Health Standard
SSS	Site-Specific Standard
SPMT	Sunoco Partners Marketing and Terminals L.P.
SVOC	semi-volatile organic compound
SVGW-NR	PADEP Groundwater Site Specific Standard Vapor Intrusion Screening Values, Non-Residental
SVIA-NR SHS	PADEP Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential
SVIA-NR SSS	PADEP Indoor Air Site Specific Standard Vapor Intrusion Screening Values, Non-Residential
SWMU	Solid Waste Management Unit
SWF	Solid Waste Facility
1,2,4-TMB	1,2,4-trimethylbenzene
1,3,5-TMB	1,3,5-trimethylbenzene
TAL	Target Analyte List
TCL	Target Compound List
THQ	Target Hazard Quotient
TDS	total dissolved solids
TR	Target Risk
TLV	Threshold Limit Value
USGS	United States Geological Survey
UST	underground storage tank
VI Guidance	Land Recycling Program Technical Guidance Manual for Vapor Intrusion into Buildings from Groundwater and Soil under Act 2
VOC	volatile organic compound
Work Plan	Work Plan for a Site Wide Approach

1.0 Introduction

Stantec Consulting Services, Inc. (Stantec) has prepared this Remedial Investigation Report (RIR) for Area of Interest (AOI) 5 on behalf of Marcus Hook Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen) regarding the Sunoco Partners Marketing and Terminals L.P. (SPMT) Marcus Hook Industrial Complex (facility), formerly the Marcus Hook Refinery, located at 100 Green Street in Marcus Hook, Delaware County, Pennsylvania (**Figure 1-1**). Sunoco, Inc. (R&M) previously operated the facility, which is currently owned by SPMT. As of December 30, 2013, Evergreen assumed the responsibility for remediation liabilities occurring at the facility on or before that date.

1.1 FACILITY DESCRIPTION AND CURRENT USE

The subject property is located on the north bank of the Delaware River in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (See **Figure 1-2**). The facility frontage extends approximately 4,800 feet (ft) along the northern banks of the Delaware River. The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures.

The area surrounding the subject property is characterized by a mixture of residential, commercial, recreational, active industrial, and vacant industrial properties and is bordered on the south by the Delaware River (**Figure 1-2**). Several underground utilities, maintained by Marcus Hook Borough and Lower Chichester Township, are present in the roadways bordering the property. Sanitary sewer and storm water sewer systems are present onsite.

SPMT currently operates the facility and has transitioned the former Marcus Hook Refinery into an operation referred to as the Marcus Hook Industrial Complex (MHIC). Current operation of the facility (24 hours per day) includes the processing and storage of light hydrocarbon products plus support facilities. Support facilities include a flare, a wastewater treatment area, boilers, air compressors, loading and unloading facilities, and the production of racing gasoline. SPMT is retrofitting the property with new facilities to process, store, chill, and distribute propane and ethane. A portion of the facility known as Phillips Island is occupied by the Marcus Hook Energy Center, a combined-cycle, co-generation, and natural gas-fired power plant owned by the Starwood Energy Group who purchase the facility from a subsidiary of NextEra Energy Resources, LCC (Florida Power & Light Company) in 2016. Sunoco LP maintains a portion of the facility for race fuels (Sunoco Race Fuels). Braskem leases the polypropylene plant (AOI 8) and the propylene splitter at 15-2 (AOI 5), along with various ancillary piping, storage, and loading.

SPMT receives, stores, and fractionates natural gasoline (feedstock), as well as stores and transfers the two fractionation products, pentane (overheads product) and light naphtha (bottoms product) at the depentanizer unit (C5 Splitter) at the MHIC. The products are shipped offsite via truck, pipeline, and/or barge. SPMT also receives, stores, and fractionates a liquefied ethane/propane transmix (feedstock), as well as stores and transfers the two fractionation products, ethane (overheads product) and propane (bottoms product) at the MHIC.

SPMT also transports and provides terminalling services for crude oil and refined products at MHIC. Crude oil and refined products (i.e. butane, alkylate, etc.) are received at the MHIC via barge, rail car, pipeline, and/or truck and temporarily stored in bulk storage tanks and caverns to facilitate movements to other transportation systems.

There are several onsite tenants utilizing steam, flare, fuel gas, wastewater treatment, air, water, and other utilities and services. The tenants include fractionation, conversion, and blending operations for a variety of products, including Sunoco Race Fuels and power generation.

Currently the site is undergoing major redevelopment in association with the Mariner East projects and other infrastructure changes. Much of the infrastructure associated with the former refining operations has been decommissioned and demolished. SPMT's future plans include providing separation of transmix or deethanized natural gas liquids into export grade propane, mixed butane, and natural gasoline.

1.2 REGULATORY SETTING

In order to fulfill the notification requirements under Act 2, a Notice of Intent to Remediate (NIR) for the facility was submitted to Pennsylvania Department of Environmental Protection (PADEP) on September 15, 2011 (**Appendix A**). The NIR expressed the intent of Sunoco, Inc. (R&M) to enter the facility into the One Cleanup Program with PADEP and Environmental Protection Agency (EPA) in order to satisfy the requirements of both the corrective action obligations under the Resource Conservation and Recovery Act (RCRA) and state requirements under the Land Recycling Program (Act 2)(PADEP, 2002). In a letter received November 8, 2011 (**Appendix A**), PADEP and EPA acknowledged this intent, and the facility was officially entered into the One Cleanup Program. The One Cleanup Program will serve as the regulatory program for site-wide remedial activities at the facility. One Cleanup Program activities undertaken in portions of the facility situated in Pennsylvania will be performed under the regulatory lead of the PADEP. Site characterization and remediation activities undertaken in portions of the facility situated in Delaware (AOI 7) will be performed under the regulatory lead of the EPA. The AOI 7 portion of the facility is currently being investigated through a Corrective Action Framework (CAF) under the RCRA First Program. Sunoco, Inc. (R&M) submitted a Work Plan for a Site Wide Approach (Work Plan) to the PADEP and the EPA on December 19, 2011 to serve as a roadmap to navigate the facility through the site characterization and remediation process to achieve site closure (Langan Engineering and Environmental Services, Inc. [Langan], 2011). As part of this Work Plan, Sunoco, Inc. (R&M) originally divided the facility into seven AOIs based on operational areas and risk-based factors including product types, potential exposure pathways, receptors, known light non-aqueous phase liquid (LNAPL) quantities, and historical information. The Work Plan also presented a schedule to characterize each of the seven AOIs. Dependent upon the results of future investigation activities, these AOIs may be further refined based on site conditions, receptors, and/or other factors. The boundaries of AOIs 5 and 7 were revised in 2012. AOI 8 was added in 2013, but was removed from the Act 2 program in 2016 (**Figure 1-2**). An updated NIR was submitted in January 2015 in order to update the facility ownership and remediation requirements, and the NIR was again updated in 2016 to remove AOI 8 from the Act 2 program (**Appendix A**).

On January 30, 2012, Sunoco, Inc. (R&M) submitted a Current Conditions Report and Comprehensive Remedial Plan (CCR) for the facility (Langan, 2012a). This was the first report submittal under the Work Plan. The CCR served as an initial assessment of the facility and drew its information from a variety of sources including historical reports, employee accounts, regulatory history, and onsite preliminary observations. The purpose of the CCR was to summarize known current and historical environmental conditions at the facility and to provide a basis for site characterization and remedial plan for the facility going forward. The CCR presented a detailed Conceptual Site Model (CSM) based on available historical information and review of historical environmental reports. The CCR also included a discussion of Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) listed in the 1991 Phase II RCRA Facility Assessment Report (1991 Phase II RFA) (A.T. Kearney, 1991).

The CAF for the RCRA Facility Investigation/Remedial Investigation of the former Marcus Hook Refinery has been developed over 2014 through 2017 with input from the USEPA and PADEP (GHD, 2017a). The CAF replaces the Work Plan as the vehicle guiding the conclusions and recommendations resulting from the facility environmental investigations.

AOI 6 was identified as the first AOI for characterization, and the RIR for AOI 6 was submitted to the PADEP on September 30, 2012 (Langan, 2012b). An RIR for AOIs 1 through 4 was submitted to PADEP on December 9, 2016 (Stantec, 2016). Work on an addendum to the AOI 6 RIR is currently in progress.

Evergreen and Stantec had a meeting with PADEP and EPA representatives on May 17, 2016 to review the completed and proposed characterization activities for AOIs 5, and activities have been implemented by Evergreen between 2013 and 2017.

1.3 FACILITY OPERATION HISTORY AND PREVIOUS INVESTIGATIONS

The facility has a long history of petroleum transportation, storage, and refining of fuels and petrochemicals. The facility was owned and operated by Sunoco since its inception as Sun Oil in 1901 and began operations in 1902. On December 1, 2011, Sunoco, Inc. (R&M) announced the indefinite idling of the main processing units at the facility due to deteriorating refining market conditions. The Marcus Hook Property was transferred to SPMT on April 1, 2013.

AOI 5 is bordered by Post Road to the north, the Middle Creek Conveyance to the east, Chester & Delaware River Railroad along the south, Phillips Island and the Delaware River on the far southwest portion, and the Delaware State Line to the west (**Figure 1-2**). AOI 5 encompasses approximately 190 acres.

AOI 5 historically contained the Lower No. 1 Tank Farm (Ship Unloading Section), former 15 & 17 Plants and associated tankage, Middle Creek, storm water tankage, and the power plant. Three gas-storage caverns also exist in AOI 5. **Figure 1-3** shows general historic use areas within AOI 5 including locations of units, if available. Referenced historical consultant reports are included in **Appendix B**.

The former 15 Plant occupied most of the western portion of AOI 5. The 15-1 Crude Unit, processed crude via atmospheric tower (A.T. Kearney, 1991). Also in unit 15-1 was unit 15-6, which historically generated MTBE which was used in gasoline blending. The 15-2S and 15-2B Gasoline Separation Plants located in the eastern portion of the 15 Plant absorbed and stripped butane, butylene propane, and propylene hydrocarbon fractions. The 15-2B plant also removed impurities and washed sulfur and phenols from the gasoline. Once this gasoline was cleaned, it was then sent to the Gasoline Blending Plant H-5 (A.T. Kearney, 1991) located in AOI 4. Also located in the 15-2 area was the Alkylation Plant which processed untreated isobutylene. This output was then reacted with sulfuric acid to produce a high octane fraction that was utilized later in blending operations (A.T. Kearney, 1991). In December of 2011, refining operations and units were idled, and permanent decommissioning of the units began in 2014. Demolition of most of the 15 Plant units was completed by 2016; however, changes to the infrastructure in the area are ongoing.

When the boundaries of AOI 5 and 7 were revised in 2012 to split the AOIs along the Pennsylvania-Delaware state boundary instead of along facility operational areas the former 17 Plant was split between AOI 5 and AOI 7. A portion of the former 17 Plant operating unit is located in northwestern AOI 5. The former 17 Plant consisted of three catalytic reformer units, 17-1A, 17-2A, and 17-1H which converted hydrocarbon fractions to cyclic and aromatic fractions. The generated output was used as an input stream for jet fuel and/or kerosene blending (A.T. Kearney, 1991). Plants 17-1FP, 17-1H, and 17-2 performed reforming operations. This process utilized a distillation column (17-1FP), a catalytic reformer (17-1H) and a UDEX unit (17-2) to generate benzene, toluene, and xylene. In December of 2011, refining operations and units were idled. The 17 Plant units were demolished in 2015 and 2016, and the western portion has been converted to a contractor parking lot.

Located to the northwest of the former processing units are the 17 Plant Tankage and 15 Plant Tankage areas, which primarily contained refined product storage tanks. Many of the storage tanks in these areas have been taken out-of-service in recent years, and some have been removed to make way for capital projects that are part of the redevelopment of MHIC. The Lower No. 1 Tank Farm (Ship Unloading Area) is located in the northeastern portion of AOI 5. This area was occupied by tankage prior to 1937. Between 1937 and 1951, a portion of the tankage in this area had been removed, but was replaced by new tankage in 1962. Various products have been stored in the Lower No. 1 Tank Farm, but it has primarily been used for crude oil storage.

The 2012 AOI boundary revision included the storm water tankage area and Phillips Island Area, located to the southeast of Middle Creek into AOI 5. These areas were the last portions of the former refinery to be developed, and according to historic aerial phots, remained largely without structures until at least 1970. The storm water tankage currently consists of aboveground storage tanks T-101, 130, and 131. The Phillips Island area is to the south and southeast of the storm water tankage. In 2000, Sunoco, Inc. (R&M) and Florida Power and Light Company (FPL) negotiated the construction of a 744-megawatt combined-cycle, co-generation, and natural gas-fired power plant on this portion of Phillips Island (about 21 acres). Sunoco, Inc. (R&M) performed a site characterization, remedial investigation, and risk assessment and then developed a cleanup plan for the Phillips Island site. An Act 2 Final Report was submitted in September 2005 (URS, 2005), and a Release of Liability Under Act 2 for this portion of the former refinery (Phillips Island Act 2 Site) was provided. The area of the Phillips Island Act 2 Site is illustrated on Figure 1-3. Remedial components of the Act 2 closure included installation of vapor intrusion mitigation systems, recovery wells, and paving. The co-generation power plant construction was completed in November 2004. In 2016, the power plant was purchased by Starwood Energy Group and is now referred to as the Marcus Hook Energy Center. The Phillips Island Act 2 Site, as defined by the Final Report (URS, 2005), will be excluded from the scope of this RIR; however, data from the Phillips Island Act 2 Site will be used to support the remedial investigation of the remainder of AOI 5 where necessary.

Based on the 1991 Phase II RFA, 56 SWMUs and three AOCs were identified within AOI 5. The approximate locations of SWMUs and AOCs in AOI 5 are shown on **Figure 1-3**:

SWMU or AOC	SWMU or AOC Description	Location
SWMU 1	Tank No. 1 Receiving Tank	Solid Waste Facility
SWMU 2	Tank No. 2 Receiving Tank	Solid Waste Facility
SWMU 3	Tank No. 3 Receiving Tank	Solid Waste Facility
SWMU 4	Tank No. 4 Sludge Storage Tank	Solid Waste Facility, east of building
SWMU 5	Tank No. 5 Sludge Decant Tank	Solid Waste Facility, east of building
SWMU 6	Tank No. 6 Collection and Transfer Tank	Solid Waste Facility
SWMU 7	Tank No. 51 Mix Tank	Solid Waste Facility
SWMU 8	Tank No. 52 Contact Tank	Solid Waste Facility
SWMU 9	Tank No. 53a Surge Tank	Solid Waste Facility
SWMU 10	Tank No. 53b Surge Tank	Solid Waste Facility
SWMU 11	Tank No. 53c Surge Tank	Solid Waste Facility
SWMU 12	Tank No. 56 Filtrate Tank	Solid Waste Facility
SWMU 13	Lime Slurry Tank	Solid Waste Facility
SWMU 14	Tank No. 54 Pre-coat Tank	Solid Waste Facility
SWMU 15	Tank No. 55 H.W. Wash Tank	Solid Waste Facility
SWMU 16	Tank No. 57 Equalizing Tank	Solid Waste Facility
SWMU 17	Catalyst Fines Silo	Solid Waste Facility
SWMU 18	Lime, Spent Clay, and Catalyst Loading System	Solid Waste Facility
SWMU 19	Sludge Receiving Trough	Solid Waste Facility
SWMU 20	Sludge Filter Press	Solid Waste Facility
SWMU 21	Filter Cake Knock-Out Area	Solid Waste Facility
SWMU 22	Hazardous Waste Container Storage Pad	Southwestern AOI 5
SWMUs 23	Old Sludge Basin	Southwestern AOI 5
SWMUs 24	Old Decant Basin	Southwestern AOI 5
SWMU 27	Phillips Island Area	Phillips Island Act 2 Site
SWMU 28	Phillips Island Maintenance Storage Area	Phillips Island Act 2 Site
SWMU 29	Phillips Island Roll-Off Staging Area	Storm water Tankage Area
SWMU 30	Phillips Island Old Drum Storage/ Small Roll-Off Area	Storm water Tankage Area

SWMU or AOC cont.	SWMU or AOC Description cont.	Location cont.
SWMU 31	Fire Fighter Training Area	Phillips Island Act 2 Site
SWMU 32	Impoundment Tank No. T-101	Storm water Tankage Area
SWMU 33	Phillips Island Surface Drainage Ditches	Storm water Tankage Area
SWMU 34	Phillips Island Sand Blasting Area	Phillips Island Act 2 Site
SWMU 45	Garage High Pressure Wash Area	Mechanical Center Area
SWMU 46	Garage Aboveground Waste Oil Tank	Mechanical Center Area
SWMU 47	Mechanical Shop Saw Dust Collector	Mechanical Center Area
SWMU 48	Mechanical Shop Sand Blast Unit	Mechanical Center Area
SWMU 49	Mechanical Shop Wire Spray Unit	Mechanical Center Area
SWMU 50	Mechanical Shop Equipment Wash Rack	Mechanical Center Area
SWMU 55	Benzene Vapor Recovery System	17 Plant Tankage Area
SWMU 56	Asphalt Plant Area	Eastern AOI 5
SWMU 60	Slop Oil Tank 388	Lower No. 1 Tank Farm (Ship Unloading Section)
SWMU 62	Heat Exchanger Bundle Cleaning Area	North of Middle Creek Conveyance
SWMU 65	1C Oil/Water Separator	Northeastern AOI 5
SWMU 66	1D Oil/Water Separator	North of Middle Creek Conveyance
SWMU 68	1F Oil/Water Separator	North of Middle Creek Conveyance
SWMU 69	1F Oil/Water Separator Feed Trench	North of Middle Creek Conveyance
SWMUs 87-94	15A-15H Oil/Water Separators	Southwestern AOI 5
SWMU 96	Middle Creek Surface Drainage System	Middle Creek Conveyance Area
AOC D	Underground Storage Tanks	Mechanical Center Area; 15 Plant
AOC E	Underground Storage Caverns	Lower No. 1 Tank Farm (Ship Unloading Section)
AOC G	1F Separator Electrical Box	Lower No. 1 Tank Farm (Ship Unloading Section)

Additionally, SWMU 25, the 12 Plant Sludge Basin, will be discussed in this RIR. SWMU 25 has generally been considered to be located in AOI 2, but characterization work described in the AOI 1-4 RIR (Stantec, 2016) did not delineate the presence of acid sludge along the southwestern boundary of the SWMU. Therefore, additional fieldwork was conducted as a part of the AOI 5 investigation.

SWMUs 1 through 21 are located within the former Solid Waste Facility (SWF), just north of Middle Creek. A Closure Certification Report for the SWF outlining the details of the closure activities for the operations in this area was submitted to PADEP (Mid-Atlantic Associates, Inc. [Mid-Atlantic], 2003). SWMUs 45 through 50, located within and in the vicinity of the Mechanical Center, should not be designated as SWMUs because they were not involved with solid waste management. Closure of these units will be requested from EPA under separate cover.

SWMU 96, the Middle Creek Surface Water Drainage System, extended across AOIs 2, 4, 5 and 7. Between 1992 and 1995, the Middle Creek Abatement Project (MCAP) was performed under the direction of the PADEP and EPA to address the site-wide wastewater system. The former site-wide wastewater system consisted of an unlined impoundment running in the general footprint of a natural surface water feature. The MCAP consisted of modifications to the storm water and process sewer systems at the site and is summarized in the Closure Plan and Post-Closure Plan, Middle Creek Abatement Project (Brown & Root Environmental and Brown & Root Braun [Brown and Root], 1993). SWMU 96 was closed by modifying the open, unlined surface water feature that drained facility wastes to a closed system that separately conveys surface water and process water. The MCAP will be discussed in additional detail in **Section 2.3.1.**

Three underground storage caverns identified by the 1991 Phase II RFA as AOC E, are present within AOI5. As these were not waste storage units, they will not be addressed under the RCRA corrective action program. Additionally, three SWMUs are completely located within the Phillips Island Act 2 Site (SWMUs 28, 31, and 34) and one SWMU (SWMU 27) is partially located in that area within the Act 2 Site. SWMUs within the Phillips Island Act 2 Site were excluded from the AOI 5 remedial investigation due to existence of an approved Act 2 Final Report for this area.

1.4 SELECTION OF CONSTITUENTS OF CONCERN

The lists of the primary constituents of concern (COCs) in soil and groundwater for AOI 5 are available as **Table 1-1** and **Table 1-2**. **Table 1-1**, the Evergreen Petroleum Short List, is an updated listing of the COCs originally identified in the Work Plan for the facility under the Pennsylvania One Cleanup Program and will be referred to as the Evergreen Petroleum Short List. This list includes all current constituents from the Short List of Petroleum Products published as Table IV-9 in Chapter IV, Section E of the Land Recycling Program Technical Guidance Manual and subsequent updates (PADEP, 2002), with the exception of the waste oil parameters. Waste oil is only stored in small tanks within the facility maintenance garages, and therefore the constituent list does not apply to the entire facility. Historically, as PADEP has made changes to constituents on the Short List of Petroleum Products, the Evergreen Petroleum Short List has been updated accordingly.

In August 2013, a PADEP email suggested a broader list of COCs should be used for site characterization of regulated substances that are not included on the PADEP Short List of Petroleum Products. An expanded COC list consisting of the PADEP Southeast Regional Office's crude oil COC list (Skinner crude list) combined with the Evergreen Petroleum Short List was created and is included as **Table 1-2** and will be referred to as the Evergreen Comprehensive List of COCs (Evergreen Comprehensive List).

The Evergreen Petroleum Short List remains the primary list of COCs for the MHIC. Since crude was processed and stored in many areas within AOI 5, the Evergreen Comprehensive List was used for most of the soil and groundwater investigation activities. The RCRA 8 metals (RCRA metals) list consisting of arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver was added to the COCs for soils in select areas (mainly SWMUs), and in many groundwater samples. In groundwater, all metals referenced indicate the dissolved fraction.

1.5 SELECTION OF APPLICABLE STANDARDS AND SCREENING LEVELS

The media of concern for AOI 5 include groundwater and soil. The potential vapor intrusion into indoor air exposure pathway was also evaluated. The approach for attaining Act 2 remediation standards for each media of concern is described in the following subsections. As the current and anticipated future use of the facility is industrial, standards for non-residential properties were chosen for comparison.

1.5.1 Groundwater

Groundwater sample results were screened against the PADEP medium-specific concentrations (MSCs) for non-residential properties overlying used aquifers with total dissolved solids (TDS) less than or equal to 2,500 milligrams per liter (mg/L), the Statewide Health Standard (SHS). Where constituent concentrations are above the SHS, Evergreen has evaluated application of the site-specific standard (SSS) using the pathway elimination option.

1.5.2 Soil

All soil results were screened using a multi-step process as described in this section. Soil sample analytical results were first screened against the PADEP non-residential, used aquifer (TDS less than or equal to 2,500 mg/L) SHS. The following process was used to select the soil SHS for each COC:

- The highest value of either 100 times the groundwater MSC or the generic value MSC was selected to represent the soil to groundwater numeric value.

- The selected used aquifer, non-residential soil to groundwater numeric value was then compared to the non-residential direct contact (NRDC) MSC (0-2 or 2-15 feet below ground surface [ft bgs], as applicable).

- The more stringent of the soil to groundwater numeric value and the NRDC MSC was selected as the SHS for initial comparison of soil sample results.

The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this RIR (**Section 4.0**) and through subsequent remedial measures which will be further described in future Act 2 deliverables. To further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step in the screening process is to compare all of the soil analytical results to the NRDC MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure to attain a standard under Act 2 were identified through comparison to the NRDC MSCs.

An exception to this soil screening process exists for lead. On February 24, 2015, Evergreen submitted a Human Health Risk Assessment (HHRA) Report (Langan, 2015) to PADEP which presented the development of a risk-based numeric SSS for lead in soil. In a letter dated May 6, 2015, PADEP approved the HHRA, and a NRDC SSS for lead of 2,240 milligrams per kilogram (mg/kg) was established. This SSS is used in place of the default 0-2 ft bgs NRDC MSC for lead and will be referred to as the lead SSS.

1.5.3 Potential Vapor Intrusion

Indoor and ambient air sample results collected in AOI 5 were screened against the EPA Region 3 Regional Screening Levels (RSL) for Industrial Air Target Risk (TR)=1E-5, Target Hazard Quotient (THQ)=0.1 (updated June 2017; EPA RSL). The EPA RSLs are used as the threshold values to determine if additional controls will be necessary to address vapor intrusion, and any such controls will be presented in the Cleanup Plan. The non-residential PADEP Indoor Air Site Specific Standard Vapor Intrusion Screening Values (SVIA-NR SHS), the non-residential PADEP Indoor Air Statewide Health Standard Vapor Intrusion Screening Values (SVIA-NR SSS), the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL); the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (REL), and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) are also provided for reference.

2.0 ENVIRONMENTAL SETTING

2.1 TOPOGRAPHY AND STORM WATER

Light Detection and Ranging (LiDAR) data obtained from the United States Geological Survey ([USGS], 2010) indicates that present-day topography is relatively flat across the facility, rising gently to the north from approximately 6 feet along the bank of the Delaware River to approximately 60 feet along Ridge Road [referenced to the North American Vertical Datum of 1988 (NAVD 88)] (**Figure 2-1**). Just north of the facility, topography steepens rapidly. Within and adjacent to the facility, some anomalies that contrast the overall topographic rise to the north are apparent. A broadly defined and subtle valley is present that originates in southeastern AOI 4 near West 10th Street and extends to the south along the eastern facility boundary. Elevations within this feature are as much as 10 feet lower than the surrounding area. Near the AOI 2/AOI 3 boundary, the valley turns to the southwest and continues through AOI 5 until it becomes obscured at the Pennsylvania-Delaware State border. This feature contained a historic creek (Linwood Creek) in the early 20th Century prior to the bulk of industrialization and associated land filling activities. Other topographic anomalies generally correlate to stockpiled fill or areas historically filled for disposal of refinery waste.

Storm water sheet flow follows topography and generally flows south across the property towards the Delaware River. The facility's combined wastewater/storm water drainage system collects process wastewater and storm water from all process areas of the facility except for the east side of the facility. In this area, storm runoff is sent to an 84-inch pipe that combines with runoff from the surrounding community and discharges at National Pollutant Discharge Elimination System (NPDES) permitted Outfall 020. All storm sewer lines, except those draining to Outfall 020, drain first to Impoundment Tank T-101, then to the separator/wastewater pretreatment plant, and then finally to the Delaware County Regional Water Quality Control Authority (DELCORA) Publicly Owned Treatment Works (POTW).

The Ethylene Complex, located in the southwest corner of the facility in Claymont, Delaware, has a segregated sewer system. One system collects process wastewater and process area storm water, and a second system collects other non-process area "clean" storm water. Non-process area storm water is discharged, via several outfalls, directly to Middle Creek and the Delaware River and is regulated under a Delaware NPDES Permit, No. DE0050288. Ethylene Complex process wastewater and process related storm water is routed to the facility's surge tanks Tank 130 and Tank-131, where it receives treatment similar to that provided for other facility waste streams.

2.2 LOCAL GEOLOGY

The facility is located on the up-dip edge of the Coastal Plain Physiographic Province near its contact with the Piedmont Physiographic Province. The Coastal Plain is characterized by relatively flat topography and is underlain by unconsolidated deposits of mud, sand, and gravel. This is in contrast to the Piedmont Province, which is characterized by steeper topography and is underlain by crystalline bedrock of the Appalachian foothills (including relatively thin and aerially discontinuous patches of Coastal Plain deposits, residual soils, and a surficial weathered bedrock zone of variable thickness). Within the Coastal

Plain, sedimentary deposits generally decrease in thickness and "pinch out" against crystalline bedrock of the Piedmont along a transition zone referred to as the "Fall Line," which is generally located along the northern boundary of the facility (**Figure 2-2**). The Coastal Plain consists of a seaward-thickening, wedge-shaped sequence of sedimentary deposits that accumulated in a variety of marine and non-marine environments. Defined geologic units/formations of the Coastal Plain outcrop and subcrop the facility and generally strike northeast/southwest, dip to the southeast, and overlie a deepening bedrock surface. In exception are geologically-recent Coastal Plain deposits related to cycles of deposition and erosion through the Delaware River valley, and potentially other tributary valleys, that are limited in extent to areas flanking the Delaware River.

According to regional geologic maps, sedimentary deposits of the Coastal Plain near the facility may range in age from Cretaceous to Holocene (**Figure 2-2**). In Pennsylvania, the Coastal Plain sediments have traditionally been mapped as belonging to the Quaternary "Trenton gravel," which is generally present between sea level and 40 feet above mean sea level (along a river terrace) with local thicknesses that are commonly less than 20 feet (Balmer & Davis, 1996). The Trenton gravel is indicated to be discontinuous in aerial extent, variable in vertical thickness and range of elevation, and primarily consists of reddish brown and gray, gravelly sand interstratified with semi-consolidated sand (limonite-cemented) and clay-silt beds (Owens and Minard, 1979). The Trenton gravel may be capped by recent (Holocene-age) alluvium deposited in tidal environments along the Delaware River margin.

In Delaware, Quaternary deposits are mapped as undifferentiated Delaware Bay Group (upper Pleistocene) consisting primarily of sandy alluvium with secondary lithologies including silty clay, peat, and sandy gravel in thicknesses up to 20 feet (Ramsey, 2005). Across the Delaware River in New Jersey, near time-equivalent surficial deposits are mapped in a similar pattern, including the Cape May Formation (Unit 2) overlain in places nearest the Delaware River by recent marsh, estuarine, and artificial fill deposits (Stanford, 2006). The Cretaceous Potomac Formation is mapped by the New Jersey Geological Survey (NJGS) to reach its up-dip limit very near the facility and as such those older deposits could subcrop Quaternary deposits in the area (Stanford and Sugarman, 2006). However, geologic mapping data supports that Potomac Formation deposits were largely removed in this area by means of erosion through the Delaware River valley. If present on the northern side of the Delaware River, the Potomac Formation would be of limited thickness, geographic extent (patches), and would likely be depth-restricted to paleochannels incised into bedrock by tributary streams draining the Piedmont. Lithologies common to the Potomac Formation in the area include very fine to coarse, quartz sand beds (with common lignite) interbedded with mud (Stanford and Sugarman, 2006; Ramsey, 2005).

Having recognized the shortcomings of available Coastal Plain geologic mapping data in Pennsylvania, Jengo (2006a) collected detailed stratigraphic information at a nearby industrial property in an attempt to resolve the existing stratigraphic nomenclature and distinguish between stratigraphic units mapped in the subsurface. Importantly, the relationship between the glaciofluvial "Trenton gravel" and older, Pleistocene-age Cape May Formation was evaluated through correlation, a depositional model, radiocarbon dating, and extensive soil sampling. Based on his findings, Jengo (2006a) established a stratigraphic framework that identifies the potential for up to 5 Quaternary-age formations/deposits in the Coastal Plain near the facility. These include, from oldest to youngest, the Pleistocene-age Cape May Formation (Units 2 and 3), lower terrace deposits, glaciofluvial deposits ("Trenton gravel"), glacial-age tributary alluvium, and Holocene-age alluvium. The identified units are lithologically similar and their distribution in the subsurface reflects a complex history of deposition and erosion since the beginning of the late Pleistocene. Importantly, Jengo (2006a) did not identify any Cretaceous or glaciofluvial ("Trenton gravel") deposits within the area studied.

According to the Bedrock Geology Map of the Piedmont of Delaware and Adjacent Pennsylvania (Schenck, Plank, and Srogi, 2000), bedrock beneath the facility is of the Wilmington Complex. The Wilmington Complex consists of metamorphosed igneous rocks including meta-volcanic units, meta-plutonic units, and un-deformed plutons. The complex is a fragment of an Ordovician-Silurian magmatic arc with later Silurian intrusions (Plank and others, 2000). The majority of the complex exists in New Castle County, Delaware. Three bedrock geologic units of the complex extend into Pennsylvania, including the Ardentown Granitic Suite of the Arden Plutonic Supersuite which is mapped to occur beneath the facility. The Silurian-age Ardentown Granitic Suite is a collection of silicic rocks that probably crystallized from a granitic magma (Srogi and Lutz, 1997). Specifically, the suite includes quartz norite, quartz monzonorite, opdalite, and charnockite. The mineralogy common to all rock types is plagioclase, orthopyroxene, clinopyroxene, potassium feldspar, quartz, and biotite.

More recently Bosbyshell (2005) published an updated bedrock geologic map that included mapping of the facility area (**Figure 2-2**). Although bedrock was not mapped beneath the Coastal Plain, that map continues to indicate that the Ardentown Granitic Suite is present beneath the majority of the facility, and that along the facility's eastern boundary area a newly identified bedrock geologic unit, the Ordovician-age Chester Park Gneiss, may be present beneath Coastal Plain sediments.

2.2.1 Facility Geology

The facility geology discussed in this RIR has been established on the basis of available lithologic data from boring logs (**Appendix C**), the principle of stratigraphic position, review of historical consultant reports and cross-sections, review of historical maps, and through separation of the major geologic units presented by Jengo (2006a). To support the discussion, three stratigraphic profiles have been prepared along the transects shown in **Figure 2-3**. The profiles presented as **Figures 2-4, 2-5, and 2-6** represent generalized geologic cross-sections developed to evaluate the subsurface beneath the facility in a regional context using borehole data available for neighboring industrial properties. The purpose of developing cross-sections extending beyond the AOI 5 boundary and in the case of Profile C – C', beyond the property boundary, was to characterize local variability in the total thickness of Coastal Plain deposits, characterize the distribution of lithologies present, identify irregularities in the bedrock surface, and identify areas where the potential for preferential groundwater flow may exist due to the distribution and interconnectedness of permeable sediments. In addition to utilizing borehole records from the Evergreen database, Stantec performed a records review into neighboring properties through State of Delaware Freedom of Information Act (FOIA) requests and obtained borehole logs from the work of Jengo (2006b). Borehole data was obtained from the State of Delaware Department of Natural Resources and Environmental Control (DNREC) for the former CitiSteel property, Texaco Claymont Terminal, and General Chemical site. AECOM provided Evergreen with test boring logs for the recent Mariner East Projects located within AOI 6 of the facility, many of which were used in this RIR. Lastly, more than 40 soil boring logs for borings performed historically at the Ethylene Complex were considered and some selected for use in the profiles crossing AOI 7.

Boring logs reviewed and borings performed as a part of the AOI 5 subsurface characterization indicate that conditions beneath the facility are complex, non-uniform, and reflective of the variability in fluvial depositional environments present through the Quaternary Period. For the purposes of this RIR, Stantec has grouped and generalized some of the observed complexity in the geologic framework underlying the facility to describe three general deposits (represented by up to nine generalized lithologies on the stratigraphic profiles) that are correlated to locally mapped stratigraphic units. In order of increasing depth these are anthropogenic fill, which generally covers the surface of the facility to varying depths, a combination of Holocene-age and Pleistocene-age alluvium consisting primarily of muddy and organic-rich sediments, and a lowermost unit comprised of Pleistocene-age alluvium that is predominantly granular in nature. These three units are described in more detail below.

Fill has been observed to underlay most of facility at variable extent and thickness ranging from a thin veneer to approximately 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. The thickest fill underlies portions of the facility nearest the current Delaware River shoreline that were created by filling and reclaiming former floodplain and estuarine environments through industrialization of the property, as can be noted by the geologic mapping data (Ramsey, 2005) and historic shoreline positions shown on **Figure 2-2**. The stratigraphic profiles presented in this RIR (**Figures 2-4 through 2-6**) indicate that significant fill deposits (up to approximately 15 feet) are also present along the axis of historic Linwood Creek (represented in modern times by the Middle Creek conveyance).

Underlying fill at the facility are predominantly muddy sediments previously referred to by Stantec (2016) as the “silty clay layer.” These deposits are correlated to Holocene and Pleistocene-age alluvium based on their character and extent. The Holocene-age alluvium is aerially constrained to the Delaware River margin and to the locations of paleovalleys associated with the positions of tributaries (e.g., Linwood, Naamans and Marcus Hook Creeks) draining or that historically drained into it (**Figure 2-7**). Because this alluvium represents the flooding and infilling of the Delaware River valley through the Holocene marine transgression, it is by nature vertically restricted to elevations that are below the present-day tidal range. Boring logs describe the Holocene-age alluvium as soft to very soft, dark gray and dark brownish gray clay/silt with abundant organic material including roots, wood, leaves, and occasional layers of sand and peat. Radiocarbon dates established by Jengo (2006a) generally constrain deposition of the bulk of the Holocene-age alluvium in this area to the last 6,000 years. Beneath the facility, the Holocene-age alluvium ranges in thickness from a few feet to approximately 35 feet.

Fine-grained deposits of the Pleistocene are common to the facility and generally define the antecedent topography that predated industrialization. Although the upper portion of Pleistocene-age alluvium is lithologically similar to that of the Holocene, it can be distinguished by its firm to stiff consistency, light gray to greenish-gray color, commonality of redoxiomorphic features (e.g., mottling), lower percentage of organic material, and appreciable gravel and pebble content. Based on lithology and stratigraphic position this deposit has been correlated to the Cape May Formation mapped in New Jersey and described in Jengo (2006a). Beneath the facility, the fine-grained Pleistocene-age alluvium ranges in thickness from a few feet to as much as 10 feet where present. It is generally thickest beneath uplands that are the erosional remnants of the Cape May Formation terrace (Jengo, 2006a) and formed the ground surface beneath much of Marcus Hook and the facility. Where missing, this deposit has usually been replaced by Holocene-age alluvium.

The lowermost lithologic unit beneath the facility is a fairly continuous and predominantly granular deposit that rests unconformably atop bedrock. Stratigraphic position and lithologic correlation to Jengo (2006a) suggest that this deposit is Pleistocene in age and may be correlative to the Cape May Formation and also could include minor lithologies of the Pleistocene-age tributary alluvium and/or Pleistocene-age lower terrace deposits. An attempt to distinguish the latter units from the Cape May Formation was not made at the facility and as such the bulk deposit is generally referred to as Pleistocene-age alluvium. Due to its apparent permeability, this unit is interpreted to form the majority of the water-table aquifer at the facility. Lithologies within the Pleistocene-age alluvium include sand, muddy sand, gravelly sand, sandy gravel with occasional cobbles, organic-rich muds, and peat. Jengo (2006a) obtained several radiocarbon dates from this interval and constrained the deposits to late Pleistocene time. An aerially extensive peat and organic-rich muddy deposit identified beneath AOIs 3 and 6 was correlated to the peat mapped by Jengo (2006a) in Trainer, Pennsylvania, which was dated at approximately 44,410 years before present (present being 1950) (**Figure 2-5**). This portion of Pleistocene-age alluvium (not including the fine-grained cap described in the preceding paragraph) is commonly 10 to 15 feet thick.

Stantec (2016) previously reported that the Cretaceous Potomac Formation may be present beneath the facility in very limited thickness and aerial extent on the basis of stratigraphic position, lithologies and colors described on historic boring logs, and correlation to mapping in neighboring states. Jengo (2006a) established a chronostratigraphy for the area near the facility that constrains the vast majority of Coastal Plain deposits to the Quaternary Period. Nonetheless, it is possible that patches of Potomac Formation remain present in the deepest areas of Coastal Plain where narrow bedrock troughs have been identified. However, none of the stratigraphic profiles presented in this RIR support the presence of mappable Cretaceous-age deposits.

Bedrock at the facility has been identified through test boring advancement and in outcroppings. Where encountered, a saprolite layer is common that contains a visible rock fabric consistent with published descriptions of Ardentown Granitic Suite crystalline bedrock. Along the northern facility boundary and within AOI 5 at the head of former Linwood Creek, bedrock was identified near surface beneath a veneer to a few feet of fill. Although the bedrock surface generally slopes south and deepens towards the Delaware River, numerous troughs with intervening pinnacles are present (**Figure 2-5**). The bedrock troughs appear to reflect the paleovalleys of most of the major tributary creeks in the area that are now underfit. The elevation of the top of crystalline bedrock (including saprolite) at the facility ranges from approximately 25 feet (e.g., AOI 5 outcrop) to deeper than -60 feet NAVD 88 near Dock 2 (**Figure 2-6**).

2.3 LOCAL HYDROGEOLOGY AND WATER BODIES

In southeastern Pennsylvania, unconsolidated sands and gravels of the Coastal Plain and fractured crystalline bedrock of the Piedmont can function as aquifers where saturated and sufficiently permeable.

Crystalline bedrock, particularly igneous and high-grade metamorphic rock types such as those associated with the Wilmington Complex, generally has low porosity with little, if any, secondary porosity/permeability yielding poor water-producing capabilities. Near the facility, these rocks have been described to yield too little water for industrial or public water supply (Balmer and Davis, 1996) and have a median well yield of less than 10 gallons per minute (gpm) (Bosbyshell, 2005). Where unconsolidated Coastal Plain sediments are present at the land surface, these rock types have been further described to "serve chiefly as a lower confining layer to retard movement of water of the overlying aquifers" (Greenman and others, 1961). Balmer and Davis (1996) provide a median yield of 50 gpm for wells screened in the "Trenton gravel" in Delaware County (according to the stratigraphic model adopted for this report the well production summarized in Balmer and Davis (1996) may include other named Pleistocene units such as the Cape May Formation). However, transmissivities may be much lower on a regional scale due to the Pleistocene deposit's limited saturated thickness resulting from local-scale heterogeneity. In addition, recent alluvial deposits, including Holocene and Pleistocene-age alluvium, are not expected to represent a significant potable water source in eastern Delaware County based on potential saline/brackish water impacts from the Delaware River (Balmer and Davis, 1996). The facility and the areas surrounding the facility are served by a public water supply and river water intakes.

2.3.1 Facility Water Bodies

Figure 2-7 shows the locations of historical streams and marshes circa 1898. In this figure, a former unnamed stream, shown on later facility maps as "Walker's Run", (Brown and Root, 1993) daylights as a spring at the slope located just to the north of Ridge Road. An earlier map atlas produced by A.H. Mueller (1913) for the Borough of Marcus Hook (**Figure 2-8**) indicates that the creek was once called Linwood Creek (as its headwaters were located near Linwood in Lower Chichester Township). Linwood Creek flowed along the western side of Hewes Avenue, beneath the Amtrak/Norfolk Southern Railway, and into AOI 4, where it meandered to the east. At that point, it curved around a topographic high (bedrock outcrop area) whose northern extent is near the present-day H-5 Control Room. Linwood Creek then coursed to the south, at which point it became flanked by fringing marsh area and flowed through present day AOI 2 at the location of the 12 Plant Sludge Basin. Near the corner of 5th Street and Hewes Avenue, Linwood Creek turned sharply to the southwest before reaching its confluence with the Delaware River in AOI 7. The present-day northeast/southwest trending portion of the former creek is shown on facility maps to be "Middle Creek" (Brown and Root, 1993). An additional stream is also noted to have existed to the west of AOI 4 and merged with Linwood Creek near its confluence with the Delaware River.

The course of surface water has been significantly altered throughout the development of the former refinery, and, until the early 1990's, Middle Creek and Walker's Run served as channels for containment and transport of both local storm water and process wastewater. This open and unlined drainage system, known as the Middle Creek Surface Drainage System, was designated as SWMU 96 in the 1991 Phase II RFA. At this time, flow of surface water from offsite through the Middle Creek Surface Drainage System had been eliminated through a system of underground bypass sewers. This sewer system, which is still in existence, transfers storm water from a portion of the drainage basin north of the MHIC (including the former headwaters of Linwood Creek) and other areas within the local community, directly to the Delaware through piping that runs along the northeastern edge of the facility (storm sewer on **Figure 1-2).** The Middle Creek Surface Drainage System was closed between 1993 and 1995 through the implementation of the Middle Creek Abatement Project outlined in the Closure Plan and Post-Closure Plan (Brown and Root, 1993). At that time, the majority of Middle Creek became contained in a conveyance system. Currently, most storm water travels through an open concrete channel, roughly following the former Walker's Run and Middle Creek beds, and process waste is conveyed within enclosed piping inside of the concrete channel. The storm water conveyance terminates just east of Blueball Avenue at a sump (Brown and Root 1993), and then goes through an onsite treatment process before being transferred to the publicly owned treatment facility at the DELCORA. Currently, a remnant of Middle Creek exists to the southwest of the concrete dam located in the vicinity of the Middle Creek Interceptor Trench Recovery System (AOI 5) and flows to the Delaware River at the southwestern corner of the facility in Delaware (AOI 7). A sheet pile bulkhead exists along the facility boundary with the Delaware River.

2.3.2 Facility Hydrogeology

At the facility, monitoring well data indicate that water levels as a whole are shallow and groundwater can occur in areas of fill and within the Holocene and Pleistocene-age alluvium at depths ranging from approximately 1 to 20 feet bgs. Groundwater generally occurs within these strata under unconfined conditions as one continuous water-bearing unit (e.g., water-table aquifer), and groundwater elevations generally decrease towards the shoreline of the Delaware River. However, perched groundwater can occur within the fill layer where the fill is present atop fine-grained deposits of the Holocene and Pleistocene, and where the top of the fine-grained cap of the Pleistocene-age alluvium is above the regional zone of saturation. In addition, groundwater within the water-table aquifer is in places confined by the significant thickness of Holocene-age alluvium, primarily along the Delaware River margin.

Presently, a network of approximately 550 monitoring wells and 120 recovery wells is used to monitor groundwater quality, understand pattern(s) of groundwater flow, and recover LNAPL within the facility (**Figure 1-2**). To evaluate recent, facility-wide patterns of groundwater flow, groundwater elevation contour maps were created for annual well gauging events performed in 2015 and 2016 (**Figures 2-9** and **2-10**, respectively). Based on the groundwater contours presented, the average hydraulic gradient across the facility is approximately 0.007 feet/foot (ft/ft), and site-wide groundwater flow is generally towards the southeast. However, some local variability in hydraulic gradient and groundwater flow direction is noted. The groundwater flow pattern appears to be affected by topography associated with former Linwood Creek in AOIs 5 and 2, and by the relocated Middle Creek along its exposed portion in AOIs 5 and 7, where there is potential for groundwater discharge to surface water. Along the eastern boundary of AOI 5, groundwater flow direction is indicated to be east towards the former Linwood Creek, and along the southern AOI 5 boundary some degree of groundwater convergence is apparent along that same feature. Groundwater elevations can be locally depressed in areas of active groundwater recovery remediation systems. Groundwater elevations along the tidal Delaware River appear to be influenced by semidiurnal tides, where maximum groundwater fluctuations of approximately 1 foot to 2.7 feet immediately adjacent to the river and 0.1 to 0.15 feet approximately 300 feet inland were recently observed in monitoring wells during a tidal study conducted by GHD Group (GHD) (**Appendix D**).

3.0 SOIL INVESTIGATION METHODOLOGY AND RESULTS

The following sections summarize the soil remedial investigation activities performed in AOI 5 between 2013 and 2017 by Stantec, Aquaterra Technologies, Inc. (Aquaterra), and Langan in coordination with Evergreen. The goal of the investigation was to characterize soil in potential source areas including open storage tank incident areas, historical releases, product handling and storage locations, and RCRA SWMUs and AOCs. In addition to collecting soil samples from borings advanced for the source-targeted soil investigations, soil samples were collected during all monitoring well installation activities regardless of whether the area was expected to contain a source in soil.

All fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Soil borings were advanced using a variety of methods including hand auger, backhoe, split spoons in conjunction with hollow stem augers, and split spoons by direct push methods. The general strategy for the investigation was to characterize soil in the 0-2 ft bgs and 2-15 ft bgs intervals. Subsurface soil samples were generally collected at the depth exhibiting the highest photoionization detector (PID) reading or above the water table. Delineation was performed to the higher the NRDC MSC and the lead SSS. Soil boring locations are shown on **Figures 3-1, 3-2, and 3-3**; **Table 3-1** summarizes the soil boring rationale, and soil boring logs are included in **Appendix C**. Soil analytical results are summarized on **Table 3-2**, which compares the results to the non-residential SHS, and **Table 3-3**, which compares the results to the higher of the NRDC MSC and the lead SSS. Soil samples were submitted to Pace Analytical Services, Inc., Accutest Laboratories, or Eurofins Lancaster Laboratories Environmental, LLC. All laboratory analytical reports from this investigation work are included in **Appendix F**. In general, soil samples were analyzed for the Evergreen Comprehensive List of Constituents, unless a shorter list of analytes was appropriate in a specific situation (i.e. delineation of specific compound exceedances). RCRA metals were added to the COC list for characterization of SWMUs.

3.1 HISTORICAL PRODUCT HANDLING/STORAGE AREAS

The main areas of historic product handling and storage in AOI 5 were the former 15 Plant Unit, the former 17 Plant unit, and their associated tankage areas. Decommissioning and demolition of the majority of the infrastructure related to these units was conducted from 2014 to 2016. In 2015, samples were collcted from accessible areas: near the 15 Plant water treatment plant (AOI5-BH-15-01 through AOI5-BH-15-04) and near the boiler house (AOI-5-BH-15-5 through AOI-5-BH-15-7, and AOI-5-BH-15-10). In March 2016, soil borings (AOI5-BH-16-01 through AOI5-BH-16-018) were completed in the 15/17 Plant areas in an approximately 250 ft by 250 ft grid with boring locations biased toward visual impacts where observed and piping runs. Soil samples were collected from the 0-2 ft bgs interval and from the 2-15 ft bgs interval when feasible. These samples were analyzed for the Evergreen Comprehensive List of COCs and some samples were also analyzed for RCRA metals to obtain areal coverage of concentrations of these compounds. In 2013, monitoring wells were installed in accessible tank dikes, and soil samples were collected from the 0-2 and 2-15 ft bgs intervals. The Evergreen Comprehensive List had not yet been established when these soil borings were completed. Soil samples were analyzed for the Evergreen Petroleum Short List, and results for base neutral semi-volatiles, volatiles, and metals constituents on the

Evergreen Comprehensive List were later retrieved where possible. The laboratory was not able to reanalyze for the acid extractable semi-volatiles, since the holding time for the samples had expired.

As infrastructure change related to capital projects continues to dominate activity at the Marcus Hook Industrial Complex, SPMT continues to take storage tanks out of service, requiring closure sampling and, in some cases, corrective action investigation activities. These activities for tank closure and tank incidents (following the NIR date for the facility) will continue to be dealt with through the storage tanks program; however, analytical data associated with these investigations have been presented in this RIR.

3.2 RCRA SWMUS / AOCS

The following summarizes all of the SWMUs and AOCs located within AOI 5 (shown on **Figures 3-1, 3-2, and 3-3**) and associated AOI 5 remedial investigation activities. Historical use summaries of these SWMUs/AOCs were obtained from the 1991 Phase II RFA completed by A.T. Kearney (1991), and are briefly provided below. All data associated with RCRA area investigations are provided in this RIR; however, closure of the SWMUs/AOCs will be requested from EPA under separate cover.

SWMUs 1-21 – Solid Waste Facility SWMUs

The following SWMUs are all located at the SWF:
- SWMU 1 – Tank No. 1 Receiving Tank
- SWMU 2 – Tank No. 2 Receiving Tank
- SWMU 3 – Tank No. 3 Receiving Tank
- SWMU 4 – Tank No. 4 Sludge Storage Tank
- SWMU 5 – Tank No. 5 Sludge Decant Tank
- SWMU 6 - Tank No. 6 Collection and Transfer Tank
- SWMU 7 – Tank No. 51 Mix Tank
- SWMU 8 – Tank No. 52 Contact Tank
- SWMU 9 – Tank No. 53a Surge Tank
- SWMU 10 – Tank No. 53b Surge Tank
- SWMU 11 – Tank No. 53c Surge Tank
- SWMU 12 – Tank No. 56 Filtrate Tank
- SWMU 13 – Lime Slurry Tank
- SWMU 14 – Tank No. 54 Pre-coat Tank
- SWMU 15 – Tank No. 55 H.W. Wash Tank
- SWMU 16 – Tank No. 57 Equalizing Tank
- SWMU 17 – Catalyst Fines Silo
- SWMU 18 – Lime, Spent Clay, and Catalyst Loading System
- SWMU 19 – Sludge Receiving Trough
- SWMU 20 – Sludge Filter Press
- SWMU 21 – Filter Cake Knock-Out Area

All of these SWMUs, with the exception of SWMU 4 and 5, are located within or directly adjacent to the SWF Building. SWMU 4 and SWMU 5 are aboveground storage tanks (ASTs) located just to the east of the building. The SWF was operational from 1979 through 2000 and was designed to treat a variety of hazardous and non-hazardous waste sludges, including API separator sludge, slop oil emulsion solids, tank bottoms, and spent filter clay (Mid Atlantic Associates, 2003). Sunoco closed the facility in 2000, and on May 2, 2003, Mid Atlantic Associates, on behalf of Sunoco, submitted the Closure Certification Report for the Solid Waste Facility, which describes the decommissioning process and sampling program.

Soil was investigated in the SWMU 4 and 5 areas for cadmium, total chromium, and lead in 1986 and 2002.

In order to provide information on the remainder of the AOI 5 constituents of concern, seven additional soil borings, AOI5-BH-16-069 through AOI5-BH-16-075 (**Figure 3-3**), were completed to further characterize these SWMUs and investigate the historic release described in **Section 3.4**.

SWMU 22 – Hazardous Waste Container Storage Pad

SWMU 22, which has been in use since the early 1980s, is a concrete-lined pad used for the storage of RCRA-regulated drums. Since this SMWU has not actively managed wastes and due its location over the location of former SWMUs 23 and 24 (discussed below), this SWMU did not warrant a separate soil investigation.

SWMUs 23 and 24 – Old Sludge Basin/ Old Decant Basin

These SWMUs consisted of two basins, located to the north of Middle Creek, measuring approximately 280 feet by 220 feet combined. As mentioned above, these former units are located beneath SWMU 22. These former units were unlined surface impoundments used for the disposal of API separator sludges and leaded tank bottoms, and were operational from the 1950s through the 1970s.

During the RCRA investigations conducted by GHD in 2015 and 2016, several soil borings were completed in the vicinity of these SWMUs, and designated as AOI 7 borings. Fourteen of these soil borings (AOI7-BH-15-001, AOI7-BH-15-002, AOI7-BH-15-004, AOI7-BH-15-005, AOI7-BH-15-008, AOI7-BH-15-011, AOI7-BH-16-008 through AOI7-BH-16-011, AOI7-BH-16-016 through AOI7-BH-16-019) are physically located within AOI 5, and are presented in this report (**Table 3-2** and **Table 3-3**, and **Figure 3-3**). Many of these samples were analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), TCL semi-volatile organic compounds (SVOCs), TCL pesticides and polychlorinated biphenyls (PBCs) and Target Analyte List (TAL) inorganics. Compounds on the Evergreen Comprehensive List and RCRA metals are displayed on the tables in this RIR.

SWMU 30 – Phillips Island Old Drum Storage/Small Roll-Off Area

SWMU 30 is located south of Middle Creek in the vicinity of the SWF. This area consisted of an unpaved area partially covered with gravel and measuring approximately 100 ft by 200 ft. It was used for temporary storage of wastes in roll-off containers while analysis was conducted to determine proper disposal. The unit was in operation from approximately 1975 through 2011 when the refinery was idled. Two soil borings, AOI5-BH-16-039 and AOI5-BH-16-040, were conducted within the footprint of SWMU 30 (**Figure 3-3**).

SWMU 32 – Impoundment Tank No. T-101

SWMU 32 is located south of Middle Creek in the vicinity of the SWF. The unit, which has been in operation since approximately 1974, consists of an open top tank, constructed to a height of 25 feet above grade and 300 feet in diameter, which has the capacity to hold approximately 13.5 million gallons. The walls are one inch thick concrete, constructed to approximately 10 feet below grade. The tank was used as an equalization and storage basin, for process and storm water from the Middle Creek Surface Drainage System (SWMU 96). Water was pumped into the tank when Middle Creek reached 7.75 feet and floating oil skimmers were designed to remove free oil from the surface of water, which was discharged into the facility's slop oil refinery system. When the level of Middle Creek fell back to a lower level, the water was gravity fed back to Middle Creek. During the MCAP, the use of T-101 was modified to consist of storage of excess storm water prior to onsite treatment and is still used for this purpose.

Soil samples were collected from six soil borings, AOI5-BH-16-041 through AOI5-BH-16-044, around the T-101 tank (**Figure 3-3**). Three of these borings along the western side of T-101 were shared for soil characterization with SWMU 33. In addition, two monitoring wells (MW-480 and MW-577) and associated soil samples are also located in the vicinity of this SWMU.

SWMU 33 – Phillips Island Surface Drainage Ditches

This SWMU was located south of Middle Creek near SWMU 32. This unit consisted of a series of unlined ditches approximately four to ten feet wide and no more than two feet deep. The ditches handled run-off from the general area and flowed east into the drains along Blueball Avenue, which discharged into SWMU 95 Combined Process/Storm water System) and eventually into SWMU 96. SWMU 96 was addressed through the MCAP during which these surface drainage ditches were filled to grade.

Three soil borings, AOI5-BH-16-041 through AOI5-BH-16-043 (**Figure 3-3**), were completed along this feature. These three soil borings were shared with SWMU 32 as discussed previously.

SWMU 55 - Benzene Vapor Recovery System

This SWMU is located to the west of Benzene Boulevard between the 17 Plant Tankage and 15 Plant Tankage. It consisted of a benzene recovery system that was used when benzene was loaded into tanker trucks. The unit was constructed of aboveground extraction column piping and equipment, an inground grated concrete column, and a sump of about 4 feet by 4 feet in area and unknown depth. This system included outer boots that surrounded the loading arms and adjoined the side of the tanker. The vapors collected in the boots were pumped to a liquid extraction unit where benzene was extracted into gas oil and was then returned to the benzene production process. The date when this unit came into operation is not known; however, it is likely it operations commenced around 1965 and ended around 1980.

Three soil borings (AOI5-BH-16-066 through AOI5-BH-16-068) and one monitoring well (MW-580) were completed around the footprint of this SWMU (**Figure 3-2**).

SWMU 56 - Asphalt Plant Area

The Asphalt Plant was located on the northern bank of Middle Creek at the intersection of Hewes Avenue and Middle Creek Road. The unit produced asphalt from the heavier fractions of crude oil. It was taken out of service in the 1970s and was partially dismantled in the 1980s. The Asphalt Plant, which measured approximately 200 feet by 100 feet, originally included eight large steel storage tanks situated on circular concrete pads, and the production system was located between two rows of tanks. The production area was concrete and had an inground grated sump, which terminated in the western portion of the plant in a large square sump. The sump included an overflow weir, which allowed for settling of solids, before the sump discharged to SWMU 95, flowed to the 1D Oil/Water Separator (SWMU 66), and then to the Middle Creek Drainage System.

Three soil borings, AOI5-BH-16-032 through AOI5-BH-16-034, were completed in the footprint of the former asphalt plant area in March 2016 (**Figure 3-1**).

SWMU 60 - Slop Oil Tank 388

This SWMU was a 3.4 million gallon, welded steel, aboveground tank with fixed roof, located on a concrete pad in the southeast corner of the facility, west of Hewes Avenue and north of the Chester and Delaware River Railroad lines. The tank received slop oil from Tank 132 (SWMU 59), where water and solids had been separated from the oil. The oil was then piped to various processing areas throughout the facility.

This tank was removed on September 3,2015. Closure soil sampling was conducted per the PADEP technical guidance document entitled *Closure Requirements for Aboveground Storage Tank Systems* (Technical Guidance, Number 263-4200-001) and the work plan entitled *Work Plan for AST Closure Activities – Greater Than 90 Feet in Diameter* (Stantec, 2015). Soil exceedances of the SHS during tank closure resulted in opening of Incident 44596. A Site Characterization Report/ Remedial Action Complete Report for this incident was submitted to the PADEP on March 27, 2017, and Incident 44596 was closed by PADEP on May 23, 2017. In addition, four soil borings, AOI5_BH-15-11 through AOI5_BH-15-14, were completed within the tank containment berm to characterize the SWMU (**Figure 3-1**).

SWMU 62 - Heat Exchanger Bundle Cleaning Area

This SWMU is located between Middle Creek and the Maintenance Shop. The unit, which was in operation before 1950, consists of a concrete pad measuring approximately 200 feet by 75 feet. Steel rails run the length of the pad on the north and south ends, and grated concrete sumps run along portions of the east and west edges of the area. Heat exchanger bundles were placed horizontally on 2 roller stands and were cleaned with high pressure water. The water drained to the sumps, which directed the water to the Combined Process/Storm Sewer System (SWMU 95) and on to Middle Creek (SWMU 96). The residues that settled in the sumps were periodically taken to the Solid Waste Facility (SWF) for treatment. These residues that settled out in the sumps were considered EPA Hazardous Waste Number K050, Heat Exchanger Bundle Cleaning Sludge. The area currently serves as a general washing pad with drainage to the current process sewer.

Four soil borings, AOI5-BH-16-024 through AOI5-BH-16-027, were completed in the vicinity of SWMU 62 in March 2016 (**Figure 3-1**).

SWMU 65 - 1C Oil/Water Separator

This SWMU was an oil/water separator located north of Middle Creek Road, east of Hewes Avenue, and west of the Middle Creek Conveyance. The unit, which began operation in 1945, was an API separator that managed wastewater generated in the Hewes Avenue tank farm area. It consisted of an inground basin measuring approximately 90 feet by 20 feet in area and about 20 feet in depth. The separated oil was piped to the slop oil system (SWMUs 58-60), the solids were periodically removed and taken to the SWF, while the treated wastewater was piped southward under the rail line to the Combined Process/Storm Sewer System (SWMU 95) and then Middle Creek (SWMU 96). This separator was decommissioned as part of the MCAP and is currently filled to grade and capped.

Four soil borings, AOI5-BH-16-045 through AOI5-BH-16-048, were completed around the former footprint of this SWMU (**Figure 3-1**).

SWMU 66 - 1D Oil/Water Separator

This SWMU was an oil/water separator located between Middle Creek Road and the Middle Creek Conveyance. The unit was an API separator that consists of an inground basin, measuring approximately 90 feet by 20 feet in area and approximately 20 feet in depth. The sludges from wastewater generated in the Asphalt Plant Area (SWMU 56) were heated by steam lines to encourage separation and the unit is covered with mesh covers. The separated oil was piped to the slop oil system (SWMUs 58-60), the solids were periodically removed and taken to the SWF, while the treated wastewater was piped southward under the rail line to the Combined Process/Storm Sewer System (SWMU 95) and then Middle Creek (SWMU 96).

Four soil borings, AOI5-BH-16-028 through AOI5-BH-16-031, were completed around this SWMU in March 2016 (**Figure 3-1**). In addition, one monitoring well (MW-583) was installed downgradient of this SWMU.

SWMU 68 - 1F Oil/Water Separator

This SWMU was an oil/water separator located between Middle Creek Road and the Middle Creek Conveyance. The unit, which has been in operation since the 1970s, was covered with steel plates and measures approximately 15 feet by 8 feet and approximately 8 feet in depth. The top of the unit was surrounded by a paved area and the unit received its wastewater from the 1F Oil/Water Separator Feed Trench (SWMU 69), which was generated from the central tank farm areas of the facility. The separated oil was piped to the slop oil system (SWMUs 58-60), the solids which were periodically removed and were taken to the SWF, and the treated wastewater was piped southward under the rail line to the Combined Process/Storm Sewer System (SWMU 95) and then Middle Creek (SWMU 96).

This SWMU was investigated along with SWMU 69 and AOC G in March 2016.

SWMU 69 - 1F Oil/Water Separator Feed Trench

This SWMU is located between Middle Creek Road and the Middle Creek Conveyance. The 50-ft trench near the 1F Separator is an existing concrete open top trench that received wastewater from the Combined Process/Storm Sewer System (SWMU 95) and delivered it to the 1F Oil/Water Separator for treatment.

Two soil borings, AOI5-BH-16-023 and AOI5-BH-16-024, were completed along the trench in March 2016 (**Figure 3-1**).

SWMUs 87-94 - 15A-15H Oil/Water Separators

These SWMUs consist of oil/water separators located to the west of the former SWF and have been in operation since approximately 1945. As originally designed, separator 15A managed wastewater from 15 Plant, 15B managed wastewater from 17 Plant, and separators 15C through 15H managed wastewater from the Middle Creek Drainage System (SWMU 96). All units are parallel API oil/water separators that together form a basin of 10,000 square feet in area and 20 feet in depth, with each separator being divided into 2 sections. Oil was retained in the first section by overflow-underflow weirs, and was manually skimmed and pumped into tanker trucks that transport it to the Slop Oil Tank V-29 (SWMU 58). Solids were removed from these separators every 6 months and were taken to the SWF, while wastewater was piped to the nearby DELCORA treatment plant in Chester, Pennsylvania. These separators are still in use as part of the current facility wastewater processing system.

Four soil borings, AOI5-BH-16-035 through AOI5-BH-16-038, were completed around this SWMU area in March 2016 (**Figure 3-3**).

AOC D - Underground Storage Tanks

Three of the four underground storage tanks (USTs) identified in the 1991 Phase II RFA are located in AOI 5. These include one gasoline tank and one diesel tank located south of the Mechanical Center, and one diesel tank located to the north of the former 15 Plant area boiler house.

One soil boring, AOI-5-BH-15-6, was completed directly adjacent to the boiler house area UST in March 2016 (**Figure 3-2**). Historic drawings for the Mechanical Center area indicate a UST area located to the south of the building. A soil boring, AOI5-BH-16-065, was completed downgradient of the UST field (**Figure 3-1**). Monitoring well, MW-573, was completed further downgradient of this area.

AOC G - 1F Separator Electrical Box

This area of concern consists of an electrical box located adjacent to the 1F Oil/Water Separator (SWMU 68). The vault was approximately 15 square feet, and the walls of the vault were observed to be approximately 8 inches thick. This vault was an access point to electrical equipment.

This SWMU was investigated along with SWMUs 68 and 69 in March 2016.

3.3 HISTORICAL RELEASES

In a review of internal facility files, the following releases were identified and investigated as part of the AOI characterization activities.

Tanks 130 and 131 (Former Tanks 7A and 7B)

Several historic releases have been noted for these tanks, between 1999 and 2006, involving slop oil, oily water, and process wastewater. These tanks store process water as part of the facility's wastewater management system. Recorded incidents involve overflows during storm events. Soil analytical data is available from monitoring wells MW-481 and MW-554 located to the south of each tank. Three additional soil borings (AOI5-BH-16-076 through AOI5-BH-16-081) were advanced on the three remaining sides along the perimeter of each tank (**Figure 3-3**).

17 Plant Area

Several historic releases consisting of naptha, xylene, benzene, jet fuel, gasoline, and reformate occurred within the former 17 Plant area. According to site personnel, releases were contained on the concrete pavement which drains to the process sewer. Furthermore, a soil sampling grid was completed across 17 Plant in early 2016 as part of the AOI 5 remedial investigation as described in **Section 3.1** (**Figure 3-2**); therefore, no further investigation was completed in this area.

15 Plant Area

Several historic releases were noted in the former 15 Plant area, specifically in the 15-2S and 15-2B units. These releases were reported to be raffinate or unspecified product. According to site personnel, these releases were contained on the concrete pavement which drains to the process sewer. Also, a soil sampling grid was completed across the former 15 Plant Area as described in **Section 3.1** (**Figure 3-2**); therefore, no additional investigation was completed in this area.

Tank 5

Three historic releases of No. 6 oil and light cycle oil (LCO; small volume or undetermined amount) were noted in the area west of Tank 5. Staining was also observed on soils near piping that passes west of the tank. Three soil borings, AOI5-BH-16-052 through AOI5-BH-16-054, were completed in the area west of the tank and were biased to areas where staining was observed (**Figure 3-1**).

V-232 and V-204

According to facility records, a release of approximately 1,221 gallons of liquids including tetra ethylene glycol, benzene, and toluene occurred on February 19, 2006 from these vessels. No documentation or additional information is available regarding this release. The exact location of these vessels within the former 15 Plant area was not confirmed from site drawings. Therefore, no additional sampling could be conducted. However, a soil sampling grid was completed across former 15 and 17 Plant areas, within which these vessels were confirmed to be have been located according to site personnel.

Hewes Road and Middle Creek Roadway (#3 Valve box)

One historic release of approximately 2,100 gallons of light crude oil was reported to have occurred on January 7, 2001. A gasket rupture on an "old white line" of the #3 valve box was determined to be the cause of materials overflowing onto the roadway. Two soil borings, AOI5-BH-16-055 and AOI5-BH-16-056, were completed in the area to characterize this release (**Figure 3-1**).

3.4 CLOSED STORAGE TANK INCIDENTS

This section provides descriptions of soil investigations related to recently closed storage tank incidents. Evergreen had addressed the historic storage tank incidents in AOI 5 for which it is responsible through the Pennsylvania Code Title 25 Chapter 245 Corrective Action Process (CAP) Program (PADEP, 2001) under separate cover. For borings associated with storage tank incidents that involve releases within tank berms, soil analytical results are presented in this RIR for informational purposes only as they relate to overall AOI 5 soil characterization. These data were presented in a Site Characterization Report/Remedial Action Completion Report (SCR/RACR) for the identified open storage tank incidents, and submitted under separate cover to the PADEP in order to satisfy the requirements of 25 PA Code Chapter 245 (Stantec, 2017). This SCR/RACR was approved by PADEP in a letter dated September 6, 2017.

AST 4 (INCIDENT 43284)

On March 21, 1994, API Separator Sludge Tank 4 separated from its ringwall and foundation, resulting in a release of approximately 7,500 barrels (315,000 gallons). The release consisted of a mixture of K051 API Separator Sludge, oil, and water. The immediate dike area was filled with sludge/oil/water and some additional areas outside of the dike were impacted. A small amount of black water migrated down the banks into Middle Creek. Release containment actions included removal of soils and free liquids, use of booms and absorbents, and pressure washing with water and detergents. No soil disposal documentation related to this incident was located during an internal file review conducted by Evergreen. There was no documentation of characterization soil sampling conducted at the time of the release. As part of the AOI 5

RI activities in 2016, seven soil borings were completed in the tank area (AOI5-BH-16-069 through AOI5-BH-16-075) to address possible impacts within the immediate tank area and along the assumed flow path towards Middle Creek. AST 4 was also designated as a RCRA SWMU. Therefore, these samples were analyzed for RCRA metals in addition to the Evergreen Comprehensive List. Concentrations of COCs did not exceed the NRDC MSC or the lead SSS, except vanadium which did not exceed the EPA RSL HQ=0.1 of 580 mg/kg.

AST 5 (INCIDENT 32009)

According to the Notice of Reportable Release (NoRR), approximately 200 gallons of gas oil leaked from a steam coil into the containment of Tank 5 on August 6, 2003. The leak was repaired and contaminated soils were removed. However, documentation regarding offsite disposal was not located during an internal file review conducted by Evergreen. There is no documentation of release assessment soil sampling related to this incident. As such, six soil borings (AOI5-BH-16-049 to AOI5-BH-16-054) were completed in the tank containment area. With the exception of one boring (AOI5-BH-16-052) where only a shallow sample was collected, shallow and deep samples were collected at each soil boring and analyzed for the Evergreen Comprehensive List of constituents. Shallow and deep soil samples were also collected in 2013 during the installation of well MW-437, and analyzed for the Evergreen Petroleum Short List. None of the samples exceeded the NRDC MSC or lead SSS.

AST 6 (INCIDENT 31923)

On July 23, 2003, a release of sodium hypochlorite (bleach) was reported from 1,500-gallon polypropylene Tank 6. A small leak was discovered in the tank, and an estimated 700 gallons of bleach was released to the secondary concrete containment area. The bleach was removed from the containment area and was put to use in the cooling towers. A follow-up letter indicates that the tank would be removed and replaced. The location of the former Tank 6 was identified to be the chemical storage building adjacent to the 15 Plant cooling towers. This tank was situated inside a concrete containment structure within a building. The July 23, 2003 release would have been confined to the secondary containment. Considering that the released bleach was immediately recovered, and the release was within an area of concrete secondary containment within a building (tertiary containment), no further characterization sampling was conducted related to this incident during AOI 5 RI activities.

AST 528 (INCIDENT 42707)

During an out-of-service tank inspection, holes were observed at the bottom of Tank 528 on June 29, 2011. Therefore, a Notice of Contamination (NOC) was submitted to the PADEP on July 13, 2011, and incident number 42707 was assigned to this suspected release. No information was available regarding assessment soil sampling related to this incident; therefore, two soil borings (AOI5-BH-16-057 and AOI5-BH-16-058) were completed in the containment area of Tank 528 during the AOI 5 RI activities in 2016. Shallow and deep soil samples were collected from each soil boring, and analyzed for the Evergreen Comprehensive List. Soil samples were also collected during the installation of well MW-450, located within the containment area of Tank 528, and analyzed for the Evergreen Petroleum Short List of parameters. There were no exceedances of the SHS for any COCs.

AST 594 (INCIDENT 1829)

Approximately 140 barrels (5,880 gallons) of crude oil was released to the containment area of Tank 594 on May 12, 2001 from the base of the tank. Free product was removed via vacuum trucks and contaminated soils were taken offsite for disposal. There was no documentation of post-excavation soil sampling conducted at the time of the release. As part of the AOI 5 RI activities in 2016, three soil borings (AOI5-BH-16-059, AOI5-BH-16-060, and AOI5-BH-16-061) were completed around the perimeter of the tank. Shallow and deep soil samples were collected from each soil boring, and analyzed for the Evergreen Comprehensive List. Soil samples were also collected during the 2013 installation of well MW-452, located within the containment area of Tank 596, and analyzed for the Evergreen Petroleum Short List of parameters. None of the samples had exceedances of the SHS for any COCs.

AST 596 (INCIDENT 1823)

On March 15, 2000, a leak at the base of Tank 596 resulted in approximately 200 gallons of crude oil being released into the tank containment area. As part of interim remedial measures, free product was removed via vacuum trucks and impacted soils were taken offsite for disposal. No soil sampling was conducted at the time to characterize this release. As part of the AOI 5 RI activities in 2016, three soil borings (AOI5-BH-16-062, AOI5-BH-16-063, and AOI5-BH-16-064) were completed around the perimeter of the tank. Shallow and deep soil samples were collected from each soil boring, and analyzed for the Evergreen Comprehensive List. Additionally, soil samples were collected in 2013 during the installation of well MW-456, located within the containment area of Tank 596, and analyzed for the Evergreen Petroleum Short List of parameters. None of the samples had exceedances of the SHS for any COCs.

AST 600 (INCIDENT 43288) and AST 602 (INCIDENTS 45604 AND 43289)

Three open incidents related to former Tanks 600 and 602 were listed in PADEP records. Records indicate the tanks were closed in 1996, and were subsequently removed. According to the NoRRs related to each incident, moisture trapped between the tank shell and insulation caused external corrosion on the shell of the tanks, resulting in pinholes leaks developing on the tank shells. Between 10 to 50 gallons of No. 6 fuel oil was estimated to have leaked during each of the three open incidents dated between February 1995 and January 1996. According to the NoRRs, tanks were taken out of service following the releases; however, there was no information available regarding release assessment activities conducted at the time.

Currently, there are no physical indications marking the former location of the tanks, owing to significant development in the area since the removal of these tanks. Based on historical facility drawings, the former location of the tanks was approximated, and four soil borings (AOI5-BH-17-010 through AOI5-BH-17-013) were completed in the area. Shallow soil samples were collected from each location and analyzed for the PADEP Petroleum Short List for Fuel Oil No. 4, 5, and 6. Groundwater was encountered at approximately 2 to 3 ft bgs in these borings, therefore, planned subsurface samples were not collected. There were no SHS exceedances for any COCs.

3.5 DELINEATION OF NRDC MSC EXCEEDANCES

Soil analytical results for the soil borings described in **Sections 3.1** through **3.4** were below the NRDC MSCs and the lead SSS with few exceptions. Delineation of those COCs detected above the NRDC MSCs during the RI activities as well as previous investigations is described below.

Tanks 613, 614, 615, 616, 617, 618, & 619 Area

Six soil samples collected during past tank closures and associated investigations for storage tanks 613 through 619 exhibited concentrations of constituents of concern (benzene, toluene, and xylenes) exceeding the NRDC MSCs (**Figure 3-2**). Delineation of these exceedences has been completed in the CAP Program. Demonstration of attainment of the SSS via pathway elimination for the NRDC MSC exceedances associated with Tanks 613, 614, and 615 was presented in a RACR dated July 24, 2015 and approved July 27, 2015. Tanks 616, 617, and 618 are currently in the CAP program, and Remedial Action Progress Reports (RAPRs) are submitted on a quarterly basis.

Tank 11

A concentration of benzo(a)pyrene exceeding the NRDC MSC was detected in one soil sample (MH11 SS-10) collected as part of the storage tank work performed at Tank 11 (**Figure 3-2**). Attainment of the SHS was established for this area using the 75/10x rule presented in the August 1, 2011 report titled Aboveground Storage Tank Release Assessment report for Tank 11 which was approved by PADEP as a 310(b) SCR in a letter dated October 7, 2011. Therefore, no additional characterization work was completed during the RI.

Tank 388

Total chromium results in three shallow samples collected from MHIC-388-4, AOI5-BH-15-11, and AOI5-BH-15-12, within the tank containment area of Tank 388, exceeded the NRDC MSCs for hexavalent chromium (**Figure 3-1**). Four soil borings (AOI5-BH-17-01 through AOI5-BH-17-04) were completed just outside the tank containment area due to access limitations related to construction activities. Shallow soil samples were collected and analyzed for total, trivalent, and hexavalent chromium, in order to evaluate whether chromium detected within the tank berm was likely hexavalent or trivalent chromium.

Area east of SWMU 5

Total chromium results in three historic shallow soil samples, AOI5-3, AOI5-4, and AOI5-5, located in the area east of SWMU 5 had NRDC exceedances for chromium. These samples were collected during the background evaluation of the area for the SWF (Mid Atlantic Associates, 2003). Four soil borings (AOI5-BH-16-082 through AOI5-BH-16-085) were completed in the vicinity of these exceedances (**Figure 3-3**). Shallow soil samples were collected and analyzed for total chromium, trivalent chromium, and hexavalent chromium, in order to evaluate the proportion of hexavalent and trivalent chromium in this area.

One shallow sample in RI soil boring, AOI5-BH-16-073, exceeded the NRDC MSC for vanadium. This exceedance is broadly delineated by soil samples already collected in the area (AOI5-BH-16-016, AOI5-BH-16-071, AOI5-BH-16-0074, and AOI5-BH-16-075) (**Figure 3-3**). Vanadium occurrences are believed to be related to historic fill; therefore, the likelihood of this exceedance being associated with the release was examined. No VOCs or SVOCs were detected above the SHS in the sample exhibiting the vanadium NRDC MSC exceedance (AOI5-BH-16-073-0-2). This indicates that it was unlikely that the vanadium was associated with a release. Therefore, Evergreen does not seek release of liability for this compound at this location. Additionally, the concentration does not exceed the EPA RSL of 580 mg/kg (HQ=0.1) and does not to pose a health risk to onsite workers. Therefore, additional sampling was not conducted for this exceedance.

SWMU 32/ T-101 Tank

The shallow sample in RI soil boring, AOI5-BH-16-044 (**Figure 3-3**), exceeded the NRDC MSC for chromium. One soil sample (AOI5-BH-16-086-0-2) was collected and analyzed for total, trivalent, and hexavalent chromium to evaluate the proportion of hexavalent and trivalent chromium in this area.

Former 15 Plant Area

Three shallow soil samples (soil borings AOI-5-BH-15-5, AOI-5-BH-15-7, and AOI-5-BH-15-10) in the former 15 Plant area, near the former boiler house, exceeded the NRDC MSC for vanadium (**Figure 3-2**). No other metals were detected above the NRDC MSCs in these samples. Additional delineation sampling was not conducted, since these exceedances are likely related to historic fill (not facility operations in the former 15 Plant Area) as evidenced by VOC and SVOC SHS attainment. Additionally, these exceedances are broadly delineated by other samples collected within the former 15 Plant area (AOI5_BH-15-01, AOI5_BH-15-02, AOI5_BH-15-03, AOI5_BH-15-04, AOI-5-BH-15-6, AOI5-BH-16-005, AOI5-BH-16-012, AOI5-BH-16-013, and AOI5-BH-16-016)

Tank 8

Ethylbenzene, benzo(a)pyrene, total xylenes, and 1,2,4-trimethylbenzene exceeded the NRDC MSCs in soil samples collected from within the Tank 8 containment berm (**Figure 3-1**). Delineation of theses exceedences has been completed through the CAP program and is described in the November 10, 2016 SCR. The remedial action is currently being addressed through the CAP program.

North of SWMUs 23 and 24

Exceedances of the SSS for lead and the NRDC MSC for arsenic were detected in 2 shallow soil samples north of the SWMU 23/24 area in soil borings AOI7-BH-16-010 and AOI7-BH-16-011 (**Figure 3-3**). Cadmium was also detected above the NRDC MSC in AOI7-BH-16-010. Additional soil borings were not completed since the exceedances are delineated by samples collected for the AOI 7 investigation of the 17 Plant (AOI7-BH-16-007 and AOI7-BH-16-009), and another of the SWMU 23/24 soil borings (AOI7-BH-16-022).

East of SWMUs 87- 94

One shallow soil sample, collected from soil boring AOI5-BH-16-037 at the eastern side of SWMUs 87- 94 (**Figure 3-3**), exceeded the NRDC MSC for cadmium. The sample concentration of 7.64 mg/kg was only slightly above the NRDC MSC of 6.1 mg/kg. The exceedance is considered to be broadly delineated by soil samples already collected in the area (AOI5-BH-16-036, AOI5-BH-16-038, AOI5-BH-16-070). Therefore, no additional soil samples were collected for this exceedance.

3.6 12 PLANT (SWMU 25) SLUDGE BASIN PERIMETER DELINEATION

On March 9, 2017, the PADEP provided report comments to Stantec supplementing approval of the AOI 1-4 RIR. Report Comment 1 indicated that the PADEP would require delineation of the acid sludge fill material in the 12 Plant Sludge Basin to the southwest of the Middle Creek Conveyance, in AOI 5. During delineation design, the aerial extent of historic marsh deposits associated with downstream portions of former Linwood Creek (also known as Walker's Run and Middle Creek (**Figure 2-7**) was used, in conjunction with existing subsurface data, as a general guide to select soil boring locations targeting the perimeter and axis of the former creek valley. The presumption was that the 12 Plant Sludge Basin location may have been selected for the historic disposal of acid sludge because of favorable topography (i.e., shallow broad valley) in the area. Presently, the historic valley that was incised by the creek is filled and exhibits only a subtle surface expression, but can be reasonably identified and targeted for evaluation through use of historic maps, high-resolution land surface elevation models (LiDAR), and subsurface data from excavations and soil borings.

Stantec coordinated and provided oversight for the five acid sludge delineation soil borings which were completed from April 17 through April 20, 2017. Top of weathered bedrock was chosen for the termination depth at each boring because it is relatively shallow in the area (outcropping locally) and would allow for evaluation of Coastal Plain deposits that may exist below acid sludge. Soil borings AOI5-BH-17-05 through AOI5-BH-17-09 were completed to bedrock utilizing a combination of two excavation methods. Borings were first excavated by backhoe to a depth of approximately 8 ft bgs to verify each location was clear of underground utilities. Once cleared, each excavation was extended to terminal depth using a truck-mounted drilling rig and hollow stem augers, accompanied by continuous split-spoon sampling. Soil borings were completed by H.T. Sweeney of Brookhaven, Pennsylvania, and Parratt Wolff, Inc., of Lewisburg, Pennsylvania. A Stantec geologist provided oversight and logging of soil cuttings and split spoon samples. Stantec also monitored breathing air within the exclusion zone for the potential presence of vapors from the excavated soil and fill materials. Soil samples that exhibited characteristics associated with acid sludge were collected and analyzed by a Stantec scientist for determination of percent acidity, pH, and density. Soil boring locations are indicated on **Figure 3-4** and detailed soil boring logs are included in **Appendix C**. Results of the acid sludge determination are included in **Table 3-4**.

Results of this subsurface evaluation indicate that the 12 Plant Sludge Basin is generally limited in aerial extent to the location where acid sludge has previously been identified. Borings AOI5-BH-17-05 through AOI5-BH-17-08 were performed along the eastern AOI 5 boundary encompassing the location where the former Linwood Creek is indicated to have turned to the southwest and crossed the area (**Figure 3-4**). Although historic fill was identified in all four perimeter borings, only boring AOI5-BH-17-07, which was performed nearest the axis of former Linwood Creek, encountered fill deposits that were consistent with the characteristics of acid sludge. AOI5-BH-17-07 also encountered the thickest interval of fill (approximately 10 feet) confirming the approximate location of the former creek's axis. As a result of this finding, boring AOI5-BH-17-09 was performed to the southwest following the downstream axis of the former creek. A thicker sequence (approximately 12 feet) of historic fill was identified at boring AOI5-BH-17-09, but only a small percentage of that fill exhibited acid sludge characteristics (occasional gravel to cobble-size pieces). This finding, considered in conjunction with subsurface data previously collected at SWMU 56 to the north and monitoring well MW-312 to the south, supports the interpretation that significant acid sludge deposits do not extend south and west of the previously identified 12 Plant Sludge Basin and thus can be considered delineated in AOI 5 in this direction. Investigation activities have also been conducted in the area of the former 7, 10 and 11 Tanks to the northwest. Prior to the commencement of intrusive well installation activities, Aquaterra performed field pH testing, and no acidic reading were observed. Additionally, no evidence of acid sludge has been observed during subsequent field activities including well installation and soil sampling. Therefore, acid sludge is considered to be contained within AOI 2 in this area.

4.0 GROUNDWATER INVESTIGATION METHODOLOGY AND RESULTS

4.1 HISTORICAL GROUNDWATER INVESTIGATIONS

The oldest available well logs for AOI 5 indicate the installation of monitoring wells occurred as early as 1990, with some existing wells likely being older. Available well construction details are summarized on **Table 4-1,** and available logs are provided in **Appendix C**. Previous consulting reports describe and present results from various historical groundwater sampling events that have been conducted. Available analytical data for wells located in AOI 5, which includes results dating back to 1995, are presented in **Table 4-2**. Major historical groundwater sampling events summarized on these tables include a site-wide sampling event performed by Aquaterra in July 2011, quarterly RCRA compliance groundwater sampling performed by multiple consultants since 1995, and annual perimeter groundwater sampling events performed by Stantec. Characterization sampling events for several AOI 5 wells were completed by Aquaterra in 2013 and by Stantec in 2015 and 2016.

4.2 WELL INSTALLATION

Several monitoring wells were installed across AOI 5 in 2013 by Aquaterra and Langan, in coordination with Evergreen. These wells were primarily installed within the tank containment berms of all accessible wells, for general expansion of the monitoring network in AOI 5. In 2015 and 2016, Stantec completed the installation of additional characterization/ delineation wells in AOI 5 as summarized below (also shown on **Table 3-1**):

- MW-554: characterize groundwater downgradient of Tank 131
- MW-555, MW-574, and MW-575: delineation of LNAPL in wells MW-45, MW-439, and MW-78, respectively
- MW-573: characterize area downgradient of former USTs in AOC D (near Mechanical Center)
- MW-577, MW-580, MW-581, MW-582, MW-583: characterize groundwater in area of SWMUs
- MW-576, MW-578, MW-579: characterize groundwater in former 15/17 Plant Areas and downgradient of Tank 613 through Tank 619

2013, 2015, and 2016 well installations were completed by Parratt-Wolffe, Inc of Syracuse, New York; and Total Quality Drilling, LLC of Mullica Hill, New Jersey. All fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Monitoring well locations are shown on **Figure 1-2.** Logs including lithologic information and well construction details are included in **Appendix C**.

4.3 GROUNDWATER GAUGING

Stantec conducts annual groundwater and LNAPL gauging of accessible existing wells. The site-wide annual well gauging event, which is typically conducted during the fourth quarter of each year, is used to identify the presence of LNAPL and determine groundwater flow patterns. Liquid level measurements, a product thickness figure, and a groundwater contour figure are submitted to PADEP in the 2nd Half Semi-Annual Marcus Hook Industrial Complex Groundwater Remediation Status Report. Liquid level measurements collected during the 2014, 2015, and 2016 annual gauging events are provided in **Table 4-3**. Groundwater elevation contours from the October 2015 and 2016 annual gauging events are included as **Figures 2-9** and **2-10**.

4.4 GROUNDWATER SAMPLING

The following section summarizes recent groundwater sampling activities performed in AOI 5 between 2014 and 2017 by Stantec and Aquaterra, in coordination with Evergreen. Fieldwork was performed in accordance with the Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Monitoring well locations are shown on **Figure 1-2.** Non-product bearing wells were generally sampled at least twice using three well volume purging methodology at intervals of a minimum of one quarter-year apart. Groundwater sampling results, including available historical results, are summarized on **Table 4-2**, and the analytical data packages are available in **Appendix F**. Most samples collected in 2014 through 2017 were analyzed for the Evergreen Comprehensive List of COCs; however, RCRA metals were added for certain wells.

To investigate potential sources of dissolved phase COCs and to obtain data to be used in future groundwater to surface water modeling, select groundwater samples were collected below representative LNAPL plume areas. Sub-LNAPL groundwater samples were collected from the following wells in AOI 5: MW-44, MW-78, MW-132, MW-439, and MW-468. The procedure for collecting samples in groundwater below LNAPL is described in **Appendix E**. The results from these sampling events are included on **Table 4-2** and can be identified by the qualifier “SL”.

In summary, nearly all COCs on the Evergreen Comprehensive List were detected in AOI 5 groundwater during the 2014-2017 sampling events. Concentrations of the following twenty compounds were detected in groundwater above the SHS during the 2014-2017 sampling events: 1,2,4-trimethylbenzene (1,2,4-TMB), 1,2-dibromoethane (EDB), 1,2-dichloroethane (EDC), 2-methylnaphthalene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenz(a,h)anthracene, ethylbenzene, indeno(1,2,3-c,d)pyrene, lead, methyl tertiary butyl ether (MTBE), naphthalene, and vanadium. Arsenic was the only RCRA metal with SHS exceedances in AOI 5 groundwater. Distribution of dissolved COCs will be discussed in detail in **Section 8.0**.

5.0 LNAPL INVESTIGATION

To investigate LNAPL in AOI 5, a comprehensive LNAPL Conceptual Site Model (LCSM) was prepared, which includes gauging data from AOIs 1 through 5 (**Appendix G)**. In general, the LCSM utilizes a technical approach to evaluate the potential mobility of LNAPL present at the facility, incorporating multiple lines-of-evidence including observations of LNAPL distribution over time, an analysis of apparent LNAPL thickness, physical and chemical laboratory analysis of LNAPL samples, and theoretical estimates of LNAPL mobility to understand whether LNAPL areas are residual (immobile), mobile, and/or migrating. As defined in the LCSM, residual LNAPL represents LNAPL that is trapped in soil pores, mobile LNAPL is LNAPL that exceeds residual saturation, and migrating LNAPL is LNAPL that is observed to spread or expand. It is noted that although mobile LNAPL includes migrating LNAPL, not all LNAPL indicated to be mobile is migrating.

The following summarizes findings and conclusions of key elements of the LCSM utilizing data gathered from literature review, historical and recent field investigations, laboratory analyses, and remediation efforts.

5.1 LNAPL DISTRIBUTION

Since 1999, LNAPL has been detected in 273 of 484 wells (56%) within AOIs 1 through 5. Overall, the percentage of wells with measurable LNAPL apparent thickness has generally decreased since 1999 and in 2016, LNAPL was detected in 147 of the 399 wells (37%) gauged within the limits of AOIs 1 through 5. **Figure 5-1** presents the maximum apparent LNAPL thickness in wells located within AOIs 1 through 5 in 2016. In addition to this figure, the LCSM (**Appendix G**) presents a historical summary of the areal distribution of LNAPL over time in five year intervals from 1999 to 2014. **Table 4-3** presents the water level and LNAPL thickness measurements for AOI 5 wells collected during annual gauging events from 2014 through 2016. In general, temporal data shows that the aerial footprint of LNAPL plumes at the facility has remained unchanged since 1999. A detailed discussion of LNAPL plume areas for AOIs 1 through 4 has been presented in the AOIs 1 through 4 RIR (Stantec, 2016). Within AOI 5, six distinct areas of LNAPL plumes are present:

- **Eastern AOI 5, near the AOI 2 boundary:** measurable LNAPL has been observed at monitoring wells MW-574 and MW-439.
- **Eastern central AOI 5:** LNAPL has been detected at several wells in the Lower No. 1 Tank Farm area, including MW-448, MW-44, MW-45, MW-78, and MW-83.
- **Isolated occurrence at MW-583:** Measurable LNAPL has been observed in MW-583 since gauging began at this well in 2016 (three rounds of data). Well MW-583 is located to the south of the Middle Creek conveyance.

- **Western AOI 5:** a few wells in the 15/17 Plant Tankage area of the AOI have been observed to contain product (MW-468, MW-472, and MW-580). Cross-gradient wells MW-472 and MW-580 were recently installed, and, therefore, have limited gauging records.

- **Middle Creek:** LNAPL has been observed in 15 wells located in the vicinity of the Middle Creek remediation system. By 2016, only seven of the gauged wells in this area exhibited measurable LNAPL, demonstrating decreasing areal extent of LNAPL in this area.

- **Phillips Island:** LNAPL has been consistently observed at the monitoring and recovery wells located within the Phillips Island Act 2 Site boundary.

A review of apparent NAPL thickness (ANT) data through time suggests that in general, LNAPL plumes at AOI 5 are not migrating since the vertical thickness of LNAPL as observed in AOI 5 monitoring wells has not been increasing. However, in the following wells increasing trends in ANT have recently been observed indicating that LNAPL in these areas might be migrating: MW-439 (eastern AOI 5, near the AOI 2 boundary); MW-83 (eastern central AOI 5); MW-468 (15/17 Plant Tankage); Middle Creek Remediation System area; and several wells in the Phillips Island Remediation System.

5.2 LNAPL SOURCE

The current and historic uses of the portions of AOIs 1 through 5 impacted with LNAPL provide some indication of the potential LNAPL sources. Many different types of petroleum products have been handled and LNAPL from various sources may be co-mingled. LNAPL characterization samples have generally indicated that the LNAPL has been degraded (**Appendix G**). LNAPL associated with older, more weathered, and degraded releases are generally less mobile. The sources of LNAPL in AOIs 1 through 4 have been presented previously (Stantec, 2016). The following summarizes available information from the historical record regarding potential LNAPL sources within AOI 5 as described in **Section 1.3** and briefly listed below:

- Storage and processing operations included in the 53 identified SWMUs for AOI 5, as reported in the 1991 Phase II RCRA Facility Assessment;
- Former 15 Plant located in western AOI 5, containing a crude oil processing unit (15-1), gasoline separation plants (15-2S/15-2B), alkylation plant (15-2), and gasoline blending (15-6 unit);
- Former 17 Plant located in the northwestern AOI 5, which includes 3 catalytic reformer units;
- Storage tanks in the former 15 and 17 Plant Tankage areas;
- Lower No. 1 Tank Farm (Ship Unloading Section) located in the northeast portion of AOI 5;
- Hewes Avenue Plant tankage area located near the AOI 2 boundary, including several ASTs and a truck loading area.

5.3 LNAPL CHARACTERIZATION

Various petroleum products have been stored, processed, and distributed throughout AOIs 1 through 5. The LNAPL observed at the facility is expected to be made up of various combinations of these products and is expected to have been modified from its source material by the effects of co-mingling, weathering, dilution, and differential solubility.

LNAPL characterization sampling has been completed for 33 wells at the facility (**Appendix G**). Interpretation of the LNAPL characterization results has provided estimates of the LNAPL source materials within each sample, and these results are helpful when identifying LNAPL sources. To facilitate visualization of the results, it is helpful to generalize the LNAPL characterization results into categories. Below is a summary of the generalized LNAPL characterization types used to group LNAPL present in AOIs 1 through 5.

- **Light distillates** include liquid petroleum gas (LPG), gasoline, and naphtha. LNAPL types grouped into the light distillate category include samples that have been primarily characterized as gasoline, heavy virgin naphtha, or reformed light naphtha. The primary components included in these products generally have carbon numbers between 3 and 10.

- **Mixes of Light/Middle Distillates** include samples that were characterized to be intermediate mixes of light and middle distillate products.

- **Middle distillates** include kerosene, jet fuel, diesel fuel, and light (#2) fuel oils. The LNAPL types grouped into the middle distillate category include samples that were characterized to be primarily middle distillate or that include significant proportions of coker naphtha mixed with middle distillate. The primary components included in these products generally have carbon numbers between 9 and 20.

- **Heavy distillates** include heavier (#4 & #6) fuel oil and heavy atmospheric gas oil. The LNAPL types grouped into the heavy distillate category include samples that were characterized as lubricating oil, residual oil, and heavy distillate. The primary components included in these products have carbon numbers between 14 and 40.

Generalized LNAPL sub-types characterized in site-specific samples include gasoline (Light Distillate), a mix of gasoline and diesel (Light/Middle Distillate), fuel oil and diesel (Middle Distillates), and heavy oils and lube oil (Heavy Distillates). The predominant generalized LNAPL type for AOI 5 may be described as follows: Light Distillate (in the vicinity of MW-468), Middle Distillate (near MW-78 and MW-83), and Heavy Distillate (near MW-439, near the Middle Creek Remediation System, and PI system).

5.4 LNAPL MOBILITY

In addition to the primary lines of evidence used in evaluating LNAPL plume stability mobility described in **Sections 5.1** and **5.3** (LNAPL distribution and characterization), secondary lines of evidence were also evaluated in the LCSM (**Appendix G**). These secondary lines of evidence include LNAPL transmissivity estimates, LNAPL mobility term evaluation, LNAPL pore entry pressure evaluation, LNAPL mobility modeling, and LNAPL distribution and recovery modeling (LDRM). These evaluations were completed for a total of 93 wells, located within AOIs 1 through 5, that had greater than 0.1 feet of apparent LNAPL thickness in 2016. A summary of the results of the secondary lines of evidence evaluation is presented below and are presented in greater detail in **Appendix G**.

- Site-specific values of LNAPL transmissivity have been estimated from historical LNAPL/groundwater recovery ratios from dual-phase and total fluid extraction wells. The results indicate a decreasing trend with current values below or approaching the limit of practicable recovery. Recent estimates of LNAPL transmissivity for the Phillips Island Remediation System have remained below the practicable recovery range lower limit, compared to a historic maximum of 0.261 ft^2/day in 2007. The estimates are based on average extraction rates for each remedial system operating as a whole. The estimates made are conservative and use the maximum estimated aquifer transmissivity based on literature estimates of hydraulic conductivity using site-specific lithologic data.

- A conservative value for the site-specific mobility term was calculated to be 1.181 x 10^{-4} cubic centimeters second per gram (cm^3s/g) which is above the practical limit of mobility.

- The critical pore entry pressure was estimated for wells that had greater than 0.1 feet of apparent LNAPL thickness in 2016. The estimated critical pore entry pressure thickness ranged from 0.20 to 27.26 feet with an average of 6.15 feet in AOIs 1 through 5. For 32 of the 93 wells evaluated, the observed LNAPL thickness was greater than the critical pore entry pressure indicating that the LNAPL observed at these wells is potentially mobile. Of these, the following are located in AOI 5 isolated areas or on the downgradient margins of known plumes and represent areas where LNAPL may be able to migrate: MW-213 (Phillips Island Area) and MW-83 in AOI 5.

- ASTM suggests that LNAPL seepage velocities less than 1x10^{-6} centimeters/second (cm/s) are indicative of functionally immobile LNAPL. As a part of this LNAPL CSM, plume velocity calculations were updated for wells with greater than 0.1 feet of ANT in 2016. Model calculated plume velocities ranged from 5.2x10^{-10} cm/s to 5.5x10^{-4} cm/s with an average velocity of 3.3x10^{-5} cm/s, indicating that LNAPL is functionally mobile in some areas of AOIs 1 through 5. Several of these wells are located in isolated areas or on the downgradient margins of known plumes. These wells represent areas where LNAPL may be able to migrate and include MW-83 in AOI 5.

- The API LDRM model was run for wells with greater than 0.1 feet of ANT in 2016. The LDRM model indicates that of the 93 wells included in the model, 16 have LNAPL transmissivity values within the practicably recoverable range and 4 wells have LNAPL transmissivity values within the lower transitional end of practicable recoverability. Based on the input parameters provided, LNAPL in the remaining 73 wells is below the practicably recoverable range. The wells with LDRM estimated LNAPL transmissivities in the practicably recoverable range in AOI 5 are MW-83, MW-210, and MW-212.

5.5 LNAPL SUMMARY

Based upon the multiple lines of evidence, the LNAPL present in AOI 5 at the facility is generally not migrating and not practicably recoverable. However, LNAPL present in the following areas of AOI 5 (that are not proximate to active remediation systems) may be mobile, able to migrate, and/or recoverable include:

- The eastern edge of the Phillips Island Remediation System plume area in AOI 5 (MW-213)
- Southeastern edge of LNAPL plume in eastern AOI 5 near the AOI 2 border (MW-439)

- 17 Plant Tankage area in northwest AOI 5 the vicinity of MW-468
- Lower No. 1 Tank Farm area in AOI 5, in the vicinity of MW-83

6.0 VAPOR INTRUSION PATHWAY INVESTIGATION

6.1 INDOOR AND AMBIENT AIR SAMPLING

To access whether a complete pathway exists for volatilization of hydrocarbons to indoor air, indoor air samples were collected in occupied onsite buildings. The size, construction, and use of all the buildings in AOI 5 were evaluated to identify which buildings contained potential receptors for volatilization to indoor air. Of the 16 buildings evaluated, five buildings were identified as requiring further evaluation of the vapor intrusion pathway. Building details are summarized on **Table 6-1**, and building locations are shown on **Figure 6-1**.

Eleven buildings were excluded from further evaluation of the vapor intrusion pathway. The 15-1 Control Room, 603 Building, Bromine Building, Co-Gen Building, Instrumentation and Electrical (I&E) Storage, Old Paint Shop, PECO Substation Warehouse, PECO Motorized Control Center, and Solid Waste Facility were excluded from the indoor air sampling program because they are all unoccupied. The Loading Rack Blast Resistant Module was excluded because there is no pathway for vapor intrusion as it is a free-standing structure with all utilities entering from aboveground. The Starwood Energy Administrative building was excluded because it is located within the Phillips Island Act 2 Site. Indoor air sampling was planned for the 15-2 Control Room. However, at the time of the sampling event in February 2017, the building was undergoing significant renovations and remodeling, including asbestos abatement in the main control room area and upgrades to the heating, ventilation, and air conditioning system. Sampling was not conducted at that time due to access restrictions and the fact that samples would not be representative of future conditions in the building.

Buildings selected for air sampling due to their status as occupied and accessible were the 854 Building, Braskem Building, the Mechanical Center, and the No. 3 Scale House. On February 15, 2017, indoor air sampling was performed in the heating season, the time which would be expected to represent the most conservative indoor conditions. All samples were collected from the lowest level of the respective structure and in accordance with The Quality Assurance/Quality Control Plan and Field Procedures Manual (**Appendix E**). Sample locations are shown on **Figure 6-1**. Samples were analyzed for volatile organic compounds (VOCs) on the Evergreen Comprehensive List, including naphthalene, by EPA method TO-15. Results are summarized on **Table 6-2**, and the laboratory analytical report is included in **Appendix F**. Field forms from the sampling event and building survey forms are included in **Appendix H**.

In addition to the indoor air samples collected in AOI 5, five ambient air samples were collected. In order to evaluate the pathway for volatilization to outdoor air, two ambient air samples were collected above LNAPL plumes and one was collected in an area of NRDC MSC exceedances in soil. Sample AOI5-AA-17-10 was collected above the LNAPL plume located near the 854 Building, sample AOI5-AA-17-11 was located above LNAPL occurring near the Middle Creek Remediation System and AOI5-AA-17-12 was located as close as was accessible to soil NRDC MSC exceedances at the 617 and 618 tanks. Two samples, AOI5-AA-17-09 and AOI5-AA-17-13, were collected to evaluate ambient air in the vicinity of indoor air samples. One additional sample was designated as a blank. Air sample locations are shown on **Figure 6-1**.

6.2 INDOOR AND AMBIENT SAMPLE RESULTS

The analytical results of the indoor and ambient air sampling are briefly discussed below. The analytical results are presented on **Table 6-2,** and the laboratory analytical report is included in **Appendix F**. Six sets of screening values are provided for reference:

- EPA RSL, TR=1E-5, THQ=0.1
- SVIA-NR SHS
- SVIA-NR SSS
- OSHA PEL
- NIOSH REL
- ACGIH TLV

The Land Recycling Program Technical Guidance Manual for Vapor Intrusion into Buildings from Groundwater and Soil under Act 2 (VI Guidance) establishes the EPA RSLs, TR=1E-5, THQ=0.1 as appropriate screening values when it can be demonstrated that vapor intrusion is the only complete exposure pathway for a receptor. Upon the completion of remediation activities, volatilization to the breathing zone will be the only potentially complete pathway for petroleum impacts in AOI 5. It is anticipated that a calculated site-specific standard will not be used, except for lead in soil, which is not a potential vapor intrusion concern.

The concentrations of VOCs detected in ambient air and indoor air were lower than the corresponding EPA RSLs in all samples.

6.3 VAPOR INTRUSION POTENTIAL TO OFFSITE RECEPTORS

Concentrations of COCs in groundwater occurring in wells located near the Pennsylvania-Delaware boundary were screened against PADEP Groundwater Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (SVGW-NR). The results of this screening are summarized on **Table 6-3**, and colorized representations of the results of this screening over the past twenty years are depicted on **Figure 6-1**. Concentrations of VOCs in groundwater are below the screening values for all Evergreen Comprehensive List COCs with the exception of benzene and ethylbenzene in the following wells:

- MW-581: Benzene was detected above the SVGW-NR of 350 ug/L in a sample collected in October 2016. Benzene was detected at concentrations below the SVGW-NR in samples collected in August and December 2016.

- MW-128: Ethylbenzene was detected above the SVGW-NR in a sample collected in 1995. MW-128 is part of the annual sampling program, and benzene has not been detected in this well since 1995.

As there was a recent exceedance of the screening values along the AOI boundary for benzene at MW-581. Facility property extends beyond this AOI boundary into AOI 7, and impacts from the facility that are present in Delaware will be addressed under the CAF and RCRA First Program. The vapor intrusion pathway for potential offsite receptors in Pennsylvania will be assessed further in a future Act 2 deliverable.

7.0 QUALITY ASSURANCE/ QUALITY CONTROL

Methods established by Evergreen to examine data quality are outlined in **Appendix E**, *Quality Assurance/Quality Control Plan and Field Procedures Manual*. All fieldwork conducted as part of the site characterization activities was performed in accordance with the procedures outlined in the *Evergreen Field Procedures Manual*, **Appendix E**. An assessment of the usability of analytical data collected as part of this investigation in accordance with the *Quality Assurance/Quality Control Plan* is included in **Appendix J**. The following sections describe specific aspects of quality assurance/quality control procedures that pertain to the activities outlined in this report.

7.1 EQUIPMENT DECONTAMINATION

All sampling equipment was either dedicated or decontaminated in accordance with the field sampling procedures to prevent cross-contamination. Prior to sampling, the equipment was decontaminated with successive rinses of detergent, potable water, and distilled water.

7.2 EQUIPMENT CALIBRATION

Air quality monitors used for both air monitoring and soil screening were calibrated prior to use. Both a zero calibration and a span calibration using gases of known concentration as recommended by the manufacturer (i.e. 100 parts per million by volume (ppm_v) isobutylene for the photoionization sensor) were performed.

7.3 SAMPLE PRESERVATION

Samples were placed directly into chemically preserved and/or non-preserved glassware provided by the analytical laboratory, as appropriate. Soil and groundwater samples were preserved and shipped at a temperature of approximately 4° Celsius (C) or less by application of ice prior to shipment to the analytical laboratory. This temperature was maintained during shipment by placing ice in zip-top bags above, around, and below the sample containers.

7.4 DOCUMENTATION

Chain-of-custody forms were maintained throughout the sampling program to document sample acquisition, possession, and analysis. Chain-of-custody documentation accompanied all samples from the field to the laboratory. Each sample was assigned a unique identifier that was recorded in the field notes as well as on the chain-of-custody document.

8.0 QUALITATIVE FATE AND TRANSPORT ASSESSMENT

8.1 SOIL

No fate and transport modeling was completed for the soil analytical results since the soil to-groundwater pathway is evaluated through groundwater data. Potential exposure pathways for AOI 5 are discussed in detail in **Section 9**.

8.2 GROUNDWATER

The following sections present a qualitative assessment of contaminant fate and transport, including an evaluation of plume stability, COC trends, and potential impacts to surface water. A future Act 2 deliverable will include quantitative groundwater modeling to further evaluate the fate and transport of contaminants at the site.

8.2.1 Geologic Framework

- The Marcus Hook Industrial Complex occurs within the up-dip edge of the Coastal Plain Physiographic Province, approximately one and a half miles southwest of the edge of the Piedmont. The Coastal Plain is defined as having relatively flat topography and as being underlain by a wedge of unconsolidated sediments that thicken in a southeasterly direction atop a sloping bedrock surface.

- As described in **Section 2.2.1**, although the subsurface conditions at the facility above bedrock are locally heterogeneous, the unconsolidated material underlying the facility can be grouped into three general lithologic units.

  1. *Anthropogenic fill*: Fill has been observed to underlay most of the facility at variable extent and thickness ranging from a thin veneer to approximately 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. The thickest fill underlies portions of the facility nearest the current Delaware River shoreline that were created by filling and reclaiming former floodplain and estuarine environments through industrialization of the property. The stratigraphic profiles presented in this RIR (**Figures 2-4 through 2-6**) indicate that significant fill deposits (up to approximately 15 feet) are also present along the axis of historic Linwood Creek (represented in modern times by the Middle Creek conveyance).
  2. *Holocene and Pleistocene-age muddy alluvium*: Underlying fill at the facility are predominantly muddy sediments previously referred to by Stantec (2016) as the "silty clay layer." The Holocene and Pleistocene-age muddy alluvium deposits have a similar lithology, both consisting of clay/silt which frequently contain organic material. They can often be distinguished from one another using consistency, color, occurrence of redoximorphic features, and gravel content. The occurrence of these muddy sediments is also different. The Holocene-age muddy alluvium is aerially constrained to the Delaware River margin and to the locations of paleovalleys of its (former and current) tributaries. Holocene-age alluvium is vertically restricted to elevations that are below the present-day tidal range. Beneath the facility, the Holocene-age alluvium ranges in thickness from a few feet to approximately 35

feet. Prior to industrialization, the fine-grained Pleistocene-age alluvium formed the ground surface beneath much of Marcus Hook and the facility. It is generally thickest beneath uplands that are the erosional remnants of the Cape May Formation terrace (Jengo, 2006a). Where missing, this deposit has usually been replaced by Holocene-age alluvium.

3. *Pleistocene-age granular alluvium*: The lowermost lithologic unit beneath the facility is a fairly continuous and predominantly granular deposit that rests unconformably atop bedrock. Stratigraphic position and lithologic correlation to Jengo (2006a) suggest that this deposit is Pleistocene in age and may be correlative to the Cape May Formation. Due to its granular texture and stratigraphic position, this unit is interpreted to form the majority of the water-table aquifer at the facility. Secondary lithologies are locally present within the Pleistocene-age granular alluvium and include organic-rich muds and peat. This portion of Pleistocene-age alluvium is commonly 10 to 15 feet thick.

Bedrock at the facility has been identified through test boring advancement and in outcroppings. Where encountered, a saprolite layer is common that contains a visible rock fabric consistent with published descriptions of Ardentown Granitic Suite crystalline bedrock. Along the northern facility boundary and within AOI 5 at the head of former Linwood Creek, bedrock was identified near surface beneath a veneer to a few feet of fill. Although the bedrock surface generally slopes south and deepens towards the Delaware River, numerous troughs with intervening pinnacles are present. The bedrock troughs appear to reflect the paleovalleys of most of the major tributary creeks in the area that are now underfit. The elevation of the top of crystalline bedrock (including saprolite) at the facility ranges from approximately 25 feet to deeper than -60 feet NAVD 88.

8.3 HYDROGEOLOGY

As discussed in **Section 2.3** of this report, groundwater occurs in the unconsolidated sediments overlying bedrock at the facility. Monitoring well data indicate that water levels as a whole are shallow and groundwater can occur in areas of fill and within the Holocene and Pleistocene-age alluvium at depths ranging from approximately 1 to 20 feet bgs. Groundwater generally occurs within these strata under unconfined conditions as one continuous water-bearing unit (e.g., water-table aquifer), and groundwater elevations generally decrease towards the shoreline of the Delaware River. However, perched groundwater can occur within the fill layer where the fill is present atop fine-grained deposits of the Holocene and Pleistocene, and where the top of the fine-grained cap of the Pleistocene-age alluvium is above the regional zone of saturation. In addition, groundwater within the water-table aquifer is in places confined by the significant thickness of Holocene-age alluvium, primarily along the Delaware River margin. Due to the highly variable nature of the composition of the unconfined aquifer, hydraulic conductivity values are expected to also be highly variable. Available aquifer testing in and near AOI 5 shows hydraulic conductivity values ranging from 1.3 feet per day (ft/d) in MP-1 (AOI 5) to 19.7 ft/day in a former well (MP-3) which was located in the southwestern corner of AOI 2 near the 12 Plant Separators just to the northeast of AOI 5 (Brown and Root, 1993). It is also assumed that areas with higher hydraulic conductivities exist where sand and gravel are present in the saturated zone. Calculations, such as those for the LNAPL mobility term discussed in **Appendix G**, use conservative estimates for hydraulic conductivity (328.10 ft/d for gravel, American Petroleum Institute [API], 2006).

The average hydraulic gradient across the facility is approximately 0.007 ft/ft, and site-wide groundwater flow is generally towards the southeast. However, some local variability in hydraulic gradient and groundwater flow direction is noted. The groundwater flow pattern appears to be affected by topography associated with former Linwood Creek in AOIs 5 and 2, and by the relocated Middle Creek along its exposed portion in AOIs 5 and 7, where there is potential for groundwater discharge to surface water. Along the eastern boundary of AOI 5, groundwater flow direction is indicated to be east towards the former Linwood Creek, and along the southern AOI 5 boundary some degree of groundwater convergence is apparent along former Linwood Creek.

Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline bedrock, particularly igneous and high-grade metamorphic rock types such as those associated with the Wilmington Complex, generally has low porosity with little, if any, secondary porosity/permeability yielding poor water-producing capabilities. Therefore, evaluation of contaminant transport within bedrock is not necessary, as it is not considered a potentially complete pathway to a receptor.

8.4 HYDROLOGY AND TOPOGRAPHY

- LiDAR (USGS, 2010) indicates that present-day topography is relatively flat across the facility, rising gently to the north from approximately 6 feet along the bank of the Delaware River to approximately 60 feet along Ridge Road (NAVD 88). Just north of the facility, steeper topography is apparent. Storm water sheet flow follows topography and generally flows southeast across the property towards the Delaware River.

- Within AOI 5, much of the surface area present is impervious or assumed to be of limited permeability.

- The Delaware River lies directly adjacent to the southeastern boundary of AOI 5.

- National Weather Service Online Weather Data (NOWData) for Philadelphia, Pennsylvania, indicates that since 1872, mean annual precipitation is approximately 42 inches (ranging from approximately 29 to 64 inches). Precipitation for Marcus Hook, Pennsylvania is assumed to be similar.

- Storm water runoff within AOI 5 is managed by the onsite storm sewer system as described in **Section 2.3.1**. Storm water is diverted to an onsite treatment facility which discharges to the POTW at DELCORA. This present-day storm sewer system generally runs in the former beds of historic Linwood Creek.

- Natural recharge of the unconfined aquifer beneath AOI 5 and proximity is assumed to be spatially variable but limited in overall capacity as a result of the high percentage of impervious surface coverage present and the fine-grained nature and extent of the alluvial deposits above the water table.

8.5 ANTHROPOGENIC FEATURES

8.5.1 Historical Fill

Anthropogenic fill has been observed to underlay most of the facility at variable extent and thickness ranging from a thin veneer to approximately 25 feet. The fill composition varies, but generally is composed of one or more of the following: silt, sand, gravel, clay, wood fragments, cinders, apparent dredged material, sludge, spent clay, and other construction/demolition or refinery materials. The thickest fill underlies portions of the facility nearest the current Delaware River shoreline that were created by filling and reclaiming former floodplain and estuarine environments through industrialization of the property. Significant fill is also present along the axis of historic Linwood Creek (represented in modern times by the Middle Creek conveyance).

8.5.2 Active Remediation Systems

In AOI 5, there are 2 active remediation systems (Middle Creek Remediation System and Phillips Island Remediation System). **Figure 1-2** shows the location of the active remediation systems and **Appendix I** provides a detailed discussion of each of the systems. System design, operation, and totalized fluid recovery can be summarized as follows:

<u>Middle Creek Remediation System</u>

- Constructed in 1997 as a dual-phase recovery system drawing from recovery wells RW-10 and RW-11.
- Located on the northern and southern side of Middle Creek in an attempt to induce hydraulic control in the immediate area and to prevent the migration of LNAPL toward Middle Creek.
- Two wells were installed in December 2004 adjacent to Middle Creek for an ozone injection pilot study. Ozone injection began in March 2005 and was discontinued during the third quarter of 2006 to allow for a total fluids recovery pump test that was completed in September 2006. Six additional monitoring wells were installed in the first quarter 2007. A pump test was performed on these wells during the week of July 30, 2007. Results from the ozone injection pilot study and total fluids pump test were used to evaluate potential upgrades to the former RW-10 and RW-11 Remediation System. Quantities of recovered groundwater and LNAPL during the pump test are unknown.
- A compressed nitrogen submersible pump was installed and operated for LNAPL recovery in MW-110 between 1999 and 2001. LNAPL recovery via a vacuum truck was performed periodically at MW-131 and MW-132 from January 2001 to February 2002 and MonPt#1 and MW-110 from May 2001 to March 2002. A total of 175 gallons of LNAPL was recovered.
- In December 2008, the RW-10 and RW-11 Remediation System was replaced with the current configuration of the Middle Creek Remediation System. Two groundwater interceptor trenches (Trench A and Trench B) were installed in the area between the 15 Plant Separator and Middle Creek in the vicinity of an oily seep. Three six-inch recovery wells were installed within the two trenches.
- Bottom loading pneumatic total fluids pumps were installed in recovery wells RW-A1, RW-B1, and RW-B2 which are powered by a 5-horsepower (hp) Kaeser rotary-screw air compressor. Each pump is equipped with a hand-operated valve that can isolate the pump from the compressor. Total fluids are pumped from each recovery well through a line to a common vault. Each discharge line is manifolded

into a common trunk line which conveys total fluids to a refinery sewer that discharges to the 15 Plant Separator.

- The system as it is currently configured was started in the beginning of June 2009 and the groundwater recovery volume reported includes total fluids pumped during the installation and testing phases. All totalizers were removed on August 20, 2009 due to iron fouling which restricted flow. Trenches are field verified as dewatered to confirm system operation on a weekly basis. Recovery for the system is estimated to be 1,831 gallons per day based on pump tests conducted in June/July 2012 and calculated using system up time.
- RW-10 recovered approximately 1.4 million gallons of groundwater and 124 gallons of LNAPL before being taken offline in 2002. RW-11 recovered approximately 1.1 million gallons of groundwater and 1,119 gallons of LNAPL before being taken offline in 2003. Since its inception, the current Middle Creek Remediation System has recovered approximately 4.4 million gallons of total fluids, including groundwater and LNAPL from testing, installation, and operation phases (through September 2017).

<u>Phillips Island Remediation System</u>

- The Phillips Island Remediation System is located along the northern shore of the Delaware River.
- Several single well LNAPL pumping systems, solar powered remediation systems, and product skimmers were installed and operated from 1995 through 2002. Many wells were destroyed due to construction activities associated with the power plant on Phillips Island.
- A LNAPL seep along the bank of the Delaware River on the Delaware portion of Phillips Island was observed on March 22, 2002. Sorbent booms were installed in the river surrounding the seeps to control any resulting sheening. To eliminate LNAPL seeps, a steel sheet pile cut-off wall was installed along the southwest edge of Upper Phillips Island between May 31 and June 17, 2002.
- Remediation system piping to four of the recovery wells (PI-1 through PI-4) was completed in September and October 2002. The Upper Phillips Island Remediation System (formerly the West Wall System) and the Lower Phillips Island Remediation System (formerly the East Wall Recovery System) were started in February 2003. The Delaware Seep System was brought online in October 2007.
- The current configuration of remediation systems at Phillips Island includes three active system areas including the Upper System, the Delaware Seep System, and the Lower System with a total of 49 pumping wells. The Upper System and Lower System operate with Wilden double diaphragm pumps and manifold skids with air actuated valves and controllers to open and close the valves. The Delaware Seep System wells contain QED AP-4 top loading pneumatic pumps.
- The Upper System and Delaware Seep System are located in a common system building. Compressed air for the Upper System and Delaware Seep System is supplied by a 20 hp Kaeser rotary screw air compressor located at the Upper System shed. Compressed air for the Lower System is supplied by a Quincy air compressor located at the Lower System shed. Fluids from the 3 active system areas are pumped through a common flow meter that is located at the Lower System shed.
- Phillips Island System configuration had previously been constructed with an oil water separators and holding tanks, but the systems were modified in 2009 to operate without oil water separators or LNAPL holding tanks. Currently, recovered total fluids from the Phillips Island Remediation System are pumped to a refinery facility sump, W21, which is pumped to the wastewater treatment facility.

LNAPL that accumulates in W21 is monitored on a weekly basis and the LNAPL is removed with a vacuum truck as needed. LNAPL recycling and/or disposal is managed by the MHIC.
- Since its inception, the Phillips Island Remediation System has recovered approximately 95.8 million gallons of groundwater and 27,492 gallons of LNAPL (through September 2017).

8.5.3 Inactive Remediation Systems

In AOI 5, there are 2 inactive remediation systems (RW-10 and RW-11 Remediation System and Well 45 Area Remediation System). **Appendix I** shows the locations and provides a discussion of each of the systems. System design, operation, and totalized fluid recovery can be summarized as follows:

RW-10 and RW-11 Remediation System

- Details regarding the inactive RW-10 and RW-11 Remediation Systems is discussed in Section 8.5.2 as they relate to the currently active Middle Creek Remediation System.

Well 45 Area Remediation System

- LNAPL was originally reported in MW-45 (a RCRA compliance monitoring point located upgradient of Middle Creek) during a gauging event conducted in October of 1992. The appearance of LNAPL in MW-45 prompted the installation of other monitoring wells in the vicinity of MW-45.
- Passive recovery via bailers and absorbent wicks commenced in June 1995 at MW-45 and in 1999 at MW-44, MW-78, MW-83, and MW-84. LNAPL recovery, via a vacuum truck, was performed periodically in MW-83 and MW-45 during 2001 and 2002.
- Due to the limited presences of LNAPL in the wells, passive recovery operations were terminated and in wells are currently on an annual liquid level monitoring schedule.
- Quantities of recovered LNAPL from the Well 45 Area are unknown.

8.6 GROUNDWATER CONSTITUENTS OF CONCERN

The following COCs were detected at concentrations above the SHS in groundwater during the 2014-2017 sampling events for AOI 5 (see **Table 4-2** for additional detail): 1,2,4-TMB, EDB, EDC, 2-methylnaphthalene, arsenic, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate (BEHP), chrysene, dibenz(a,h)anthracene, ethylbenzene, indeno(1,2,3-c,d)pyrene, lead, MTBE, naphthalane, and vanadium. Available historical analytical data from previous groundwater sampling events (2013 and prior) were reviewed by Stantec. These data indicate the following additional COCs were identified at concentrations exceeding the SHS during historic groundwater sampling events in AOI 5: chromium, cobalt, toluene, xylenes, and zinc.

8.7 GROUNDWATER PLUME LOCATIONS

For this qualitative assessment of contaminant fate and transport, Stantec evaluated available analytical data from Evergreen's electronic database for results of the characterization of AOI 5. As these investigations have covered a large area, and there are numerous COCs that have been detected in exceedance of the SHS throughout the AOIs, areal occurrence of exceedances was limited to select COCs that could be used as qualitative-level proxies. The following proxy compounds were selected based on a variety of characteristics including water solubility, and areal extent of impact. The proxy compounds are listed with other COCs that are generally observed to be co-located with the proxy compounds.

Proxy: COCs Represented

- **Benzene**: EDB, EDC, ethylbenzene, and toluene
- **MTBE**
- **1,2,4-TMB**
- **Benzo(a)pyrene**: benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene
- **Chrysene**
- **BEHP:** 2-methylnaphthalene
- **Naphthalene**
- **Arsenic**
- **Lead**
- **Vanadium**

The following discussions of current dissolved phase plumes in AOI 5 use these ten proxy COCs to qualitatively represent all groundwater impacts. Isoconcentration maps depicting the distribution of these COCs (maximum concentrations detected between 2014 and 2017) are provided in **Figures 8-1 through 8-10**. In addition to data from AOI 5, analytical data in neighboring AOIs 1 through 4 and AOIs 6 through 8 are provided to show contaminant distribution across internal AOI boundaries. It should be noted that the groundwater data presented for areas outside AOI 5 are not comprehensive set and is included for informational purposes only; a complete data set and more comprehensive evaluation of contaminant plume distributions and related discussions was presented recently for AOIs 1 through 4 (Stantec, 2016) or will be presented in the remedial investigation reports for AOIs 6 and 7.

Golden Software's Surfer® 13 was used to interpolate the groundwater data to produce the colorized grids presented in this RIR. Block kriging was the most commonly used method of interpolation. Grid residuals were evaluated and the interpolated surfaces were subsequently contoured and imported into a geographic information system (GIS) for display and evaluation. The color maps utilized in **Figures 8-1 through 8-10** are limited to the concentration ranges observed to be above the SHS for each proxy compound (i.e., grid areas with interpolated concentrations below the indicated standard are not colorized). In addition to block kriging, other gridding methods were also evaluated with the goal of generating plume maps which best represented known hydrogeological conditions, contaminant geochemistry, contaminant source areas, as well as the spatial and statistical distribution of available analytical data. Under these considerations, the natural neighbor gridding method provided reasonable VOC and semi-volatile organic compound (SVOC) distributions across the facility. The inverse distance to power method was used to generate a grid for lead, which had uneven data distribution with less than 300 observations. Due to limited data points for arsenic (less than 100 observations over a large area), a simple linear point kriging method was used. In some cases, certain assumptions about anisotropy and angle were made based on inferred hydrologic conditions at the facility.

Distribution of groundwater plumes above the relevant SHS for each of the ten proxy COCs in AOI 5 are summarized below. Operational areas described below are shown on **Figure 1-3**.

- **Benzene (Figure 8-1):** Benzene was detected in a majority of wells in AOI 5. A benzene plume is observed to encompass a majority of Lower No. 1 Tank Farm, 15/17 Plant Areas, and southern AOI 5 near Middle Creek towards Phillips Island. A plume core representing concentrations in excess of 500 µg/l can be observed near MW-575, near MW-455 and MW-456, and near MW-443.

- **MTBE (Figure 8-2):** SHS exceedances of MTBE are limited to two general areas of AOI 5: In 17 plant near MW-579, and near the boundary with AOI 2 at MW-434 and MW-438. An MTBE plume is interpolated into the southeast corner of AOI 5, owing to elevated concentrations in the area in AOIs 2 (MW-519 and MW-520), AOI 3 (MW-491), and AOI 6 (MW-312).

- **1,2,4-TMB (Figure 8-3):** 1,2,4-TMB exceedances appear to be limited, with plume cores (greater than 250 micrograms/liter [µg/l]) centered around select wells in 15/17 Plant area tankage (MW-468, MW-579, MW-460), and the Lower No.1 Tank Farm area (MW-455 and MW-456).

- **Benzo(a)pyrene (Figure 8-4):** Benzo(a)pyrene exceedances are located in two main areas of AOI 5: in the Lower No. 1 Tank Farm area around MW-44, in the area around MW-576 and MW-577 towards Middle Creek Conveyance and the boundary with AOI 7. Isolated plumes are interpolated in AOI 5, owing to elevated concentrations in neighboring AOIs: along the northern boundary with AOI 4, and along the eastern boundary with AOI 2.

- **Chrysene (Figure 8-5):** Chrysene exceedances are limited to isolated areas in Lower No. 1 Tank Farm near MW-44, and near the Middle Creek Conveyance area near MW-576 and MW-577.

- **BEHP (Figure 8-6)**: SHS exceedances of BEHP are limited to isolated occurrences in the western and southern part of AOI 5: MW-579, MW-461, MW-468, MW-132, and MW-480.

- **Naphthalene (Figure 8-7):** Three areas of SHS exceedances for naphthalene exists in AOI 5: in the 15/17 Plants near MW-579 and MW-468, and in the Lower No. 1 Tank Farm near MW-455 and 456.

- **Arsenic (Figure 8-8):** Two isolated exceedances of arsenic are present within AOI 5 at MW-579 in 17 Plant and MW-582. A plume is predicted in the east near the boundary with AOI 2, due to an arsenic plume core centered over the acid sludge basin.

- **Lead (Figure 8-9):** Lead exceedances in AOI 5 are found at MW-581 in the Middle Creek Conveyance Area, and at MW-455 and MW-456 in the Lower No. 1 Tank Farm. Cross boundary plumes are predicted at the northern and eastern AOI boundaries, owing to elevated concentrations in AOIs 4 and 2, respectively.

- **Vanadium (Figure 8-10):** Isolated areas of vanadium exceedances are found across AOI 5; most notably, concentrations in excess of 40 µg/l are found in MW-446 in the Lower No. 1 Tank Farm area, MW-581 near the Middle Creek Conveyance, and MW-478 in the northwestern corner of AOI 5.

Delineation of groundwater plumes in AOI 5:

- AOIs 1, 4, and 8 of the facility are located to the north and hydraulically upgradient of AOI 5. Cross-boundary plumes of several COCs (e.g. benzene, benzo(a)pyrene, lead) are present along the AOI 4 and AOI 5 boundary at Post Road, however they are generally delineated within the northern reaches of AOI 5.

- Concentrations of COCs were not detected above the SHS in AOI 2 wells that are located along the northeastern property boundary, which is located side gradient to downgradient of AOI 5. Therefore, groundwater impacts across the AOI5 and AOI 2 boundary are not expected to be impacting offsite receptors in that direction.

- Several COCs (e.g., benzene, benzo(a)pyrene, arsenic and lead) are found near the western AOI 5 boundary with AOI 7. The potential for offsite migration of impacted groundwater from AOI 5 exists in this area based on the identified groundwater flow patterns presented in this RIR. Delineation along the AOI 5/AOI 7 boundary is incomplete for some of these compounds. However, AOI 7 is part of a separate investigation under the USEPA in the State of Delaware. It should be noted that the wells in the northwestern corner of AOI 5 have not exhibited SHS exceedances in groundwater in recent events, with the exception of vanadium in MW-478 noted above.

Sources of COCs to Groundwater in AOI 5:

- Concentrations of benzene, benzo(a)pyrene, and MTBE above the SHS occurring in the eastern portion of AOI 5, along the northern boundary with AOI 2, are likely associated with the 12 Plant Sludge Basin (SWMU 25), or with product tankage and/or piping in the area. Concentrations of MTBE above the SHS occurring along the southern boundary with AOI 2 (and confluence with AOIs 3 and 6) may be attributed to the 12A oil/water separator or product piping as presented in the AOIs 1 through 4 RIR (Stantec, 2016). Additionally, and as discussed in **Section 3.6**, the extent of the former acid sludge basin is believed to follow a historic stream valley along the current Middle Creek Conveyance; and as such, the distribution of these COCs are also expected to follow a similar pattern.

- Concentrations of benzene, benzo(a)pyrene, lead exceeding the SHS are detected in northern AOI 5, downgradient of the AOI 4. These COC exceedances along Post Road are in proximity to presence of LNAPL. Therefore, it is assumed that LNAPL is the source of dissolved compounds in this area.

- Plume cores centered around the same wells in 15/17 Plant (for eg. MW-468 and/or MW-579) and/or the Lower No. 1 Tank Farm (MW-455 and MW-456) areas for benzene, benzo(a)pyrene, MTBE, 1,2,4-TMB, naphthalene, and BEHP are likely related to product releases from 15/17Plant operations and/or from tankage in the respective areas.

- Plume core in the vicinity of MW-44 for benzene, 1,2,4-TMB, benzo(a)pyrene, and chrysene correlate with LNAPL in the vicinity.

- In AOI 5, elevated arsenic and VOCs are present in MW-579, MW-582, and MW-577. The presence of dissolved hydrocarbons may be causing the reduction of iron hydroxides in soils, which in turn releases naturally-occurring, solid state arsenic into groundwater, a process described in Cozzarelli et al. (2016).

- Elevated concentrations of dissolved arsenic and lead are centered over the 12 Plant Sludge Basin in AOI 2. Due to the low pH in groundwater associated with the occurrence of acid sludge in this area, elevated concentrations of dissolved metals would be expected as a result of leaching of naturally-occurring metals. Thus, the acid sludge may be a source of elevated metal concentrations occurring in the northeastern portion of AOI 5. As discussed previously, the former acid sludge basin is believed to extend into southeastern AOI 5 along the Middle Creek Conveyance, and therefore elevated dissolved metal concentrations in that portion of AOI 5 are also attributable to the presence of acid sludge.

- Vanadium is expected to represent only a fractional component of the facility's current and historic petroleum products. While elevated vanadium concentrations coincide with certain instances of elevated VOC concentrations, the source of vanadium is likely found in historic fill at the facility. As mentioned previously for arsenic and lead, metal dissolution and release to groundwater can occur in the presence of dissolved hydrocarbons.

8.8 GROUNDWATER PLUME STABILITY ASSESSMENT

The monitoring well network has increased significantly since the initiation of the remedial investigation phase work in 2013. It is likely that many of the plume areas currently observed, particularly in AOI 5 where well coverage was sparse, may have existed historically. Prior to the expansion of the well network, the main source of groundwater analytical data available was limited to annual perimeter groundwater sampling events that have been conducted since the mid-1990s. All wells with greater than three years of historical results and more than three data points were examined for trends. The AOI 5 monitoring well network was expanded substantially in the 2015-2016 timeframe; however, a majority of these wells have only been sampled twice since installation. These wells will continue to be part of the AOI 5 groundwater monitoring program, in order to obtain a comprehensive and long-term analysis of groundwater plume stability.

To qualitatively assess the stability of the identified groundwater plumes, available historical groundwater analytical results were analyzed. Stantec utilized concentration plots (**Figures 8-11** through **8-14**) to evaluate overall plume size and COC concentration trends. Discernible long term trends over the record of sampling have been found for benzene, MTBE, arsenic, and lead in various facility wells, and have been presented previously for wells in AOIs 1 through 4 (Stantec, 2016). **Figures 8-11** through **8-14** show concentration trends for these four compounds in select AOI 5 wells. Monitoring wells, MW-455 and MW-86, are located in central AOI 5 within identified plume cores, discussed in **Section 8.7**. MW-128 is located in the northwestern corner of AOI 5, at the property boundary. MW-15 is located along the eastern boundary with AOI 2, west of the acid sludge basin. Monitoring wells, MW-109 and MW-129, are located in the southwestern portion of AOI 5, along the Middle Creek Conveyance and side-gradient to upgradient of AOI 7. In general, these plots show decreasing trends with the majority of recent data being below the SHS.

8.9 POTENTIAL ONSITE AND OFFSITE RECEPTORS

Based on the identified impacts to groundwater in AOI 5, Stantec has evaluated the following as potential receptors.

- The potential for vapor intrusion into occupied buildings in AOIs 5 was evaluated. Concentrations of COCs were below the EPA RSLs in indoor air samples collected from occupied buildings and in ambient air samples.
- Infiltration of groundwater into underground utilities has the potential to generate vapors along subsurface corridors. Evergreen has not identified these types of preferential pathways within AOI 5 specifically. However, this is a known pathway in adjacent AOIs, and options to address these potential preferential pathways will be addressed in the Cleanup Plan.
- Direct vapor migration into the vadose zone is also a potential pathway. Concentrations of VOCs in groundwater in wells located near the Pennsylvania-Delaware border were screened against the SVGW-NR. One COC exceedance of this screening value was detected for benzene in MW-581. This well is screened in gravelly coarse sand in an area interpreted to represent a position of the former Linwood Creek. Groundwater may preferentially flow along this feature beyond the AOI 5 boundary.
- Other potential receptors for volatilization of constituents in groundwater were not identified within the specified proximity distances that warranted further vapor intrusion evaluation.
- Dissolved COCs in AOI 5 may migrate from groundwater to the surface water of Middle Creek and the Delaware River. The potential impact to surface water will be further evaluated through a Cornell Mixing Zone Expert System (CORMIX) model that will be presented in the Cleanup Plan. Cumulative loading of COCs from groundwater to surface water will be evaluated with human consumption of fish designated as the exposure pathway of concern.
- No known potable water supply wells exist at or in close proximity to AOIs 5. The results of a sitewide well search using the Pennsylvania Groundwater Information System (PaGWIS) database and a Freedom of Information Act request to the Delaware Department of Natural Resources and Environmental Control is included in **Appendix K**.
- Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline rocks generally have no porosity with little, if any, secondary

porosity yielding poor water producing qualities. Therefore, evaluation of contaminant transport within bedrock is not necessary, as it is not considered a potentially complete pathway to a receptor.

9.0 ECOLOGICAL ASSESSMENT

On June 22, 2017, an updated survey of endangered, threatened, and special concern species and habitat was conducted by submitting a request to the Pennsylvania Natural Diversity Inventory (PNDI) database. The PNDI search identified no known impact results from the Pennsylvania Game Commission and the U.S. Fish and Wildlife Service. The PNDI search identified potential threatened and endangered species impacts that required further review by the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) and the Pennsylvania Fish and Boat Commission (PAFBC). Stantec submitted consultation letters to the PA DCNR and the PAFBC to request further investigation and clearance based on potential ecological impact. A response indicating that no adverse impacts are expected to species or habitats of special concern was received from the PA DCNR on June 30, 2017. On July 11, 2017, a response was received from the PAFBC indicating that rare or protected fish species are known in the vicinity of the site. PAFBC expressed concern regarding changes to the aquatic environment. Any work conducted at the site is required to comply with the recommendations made by the PAFBC. The response from PAFBC did not identify the unnamed endangered and threatened species that were listed on the PNDI search. After a call to request this information, Stantec received a follow-up response letter from the PAFBC on November 9, 2017. This letter identified the endangered species as the Shortnose Sturgeon and Atlantic Sturgeon and the threatened species as the Eastern Redbelly Turtle. The PNDI search and agency response letters are valid for two years. All PNDI documentation is included in **Appendix L**.

The majority of AOIs 5 is covered with impervious surfaces, soil, or gravel. The soil and gravel-covered areas of AOIs 5 are not likely to serve as a breeding area, migratory stopover, or primary habitat for wildlife. The U.S. Fish and Wildlife Service National Wetlands Inventory online mapping tool was consulted to assist in identification of wetlands in AOI 5 (**Appendix L**). Wetland identified by the mapping tool show the Middle Creek Area and Delaware River as wetlands located in and adjacent to AOI 5. These water bodies cannot be ruled out as wetlands of exceptional value due to the proximity to fish species of special concern. Additional ecological risk assessment will be conducted in a future Act 2 deliverable to determine whether COC impacts from AOI 5 constitute an unacceptable risk to ecological receptors.

10.0 CONCEPTUAL SITE MODEL

Through comprehensive file review and characterization activities performed as a part of this RIR, Stantec's conceptual understanding of the present conditions identified at AOIs 5 is summarized as follows.

10.1 DESCRIPTION AND SITE USE

- The facility is located on the north bank of the Delaware River in the Borough of Marcus Hook, Delaware County, Pennsylvania, with portions of the facility in Lower Chichester Township, Pennsylvania and Claymont, New Castle County, Delaware (See **Figure 1-2**). The facility, which is located on industrial property, covers approximately 585 acres of land with access restricted by fencing and security measures. Current operations at the facility consist of the processing and storage of light hydrocarbon products plus support facilities.

- The area surrounding the subject property is characterized by a mixture of residential, commercial, recreational, active industrial, and vacant industrial properties.

- The facility has a long history of transportation, storage, and refining of fuels and petrochemicals with operations beginning in 1902 by Sun Oil. The property was transferred from Sunoco, Inc. (R&M) to SPMT in 2013, at which time the transition from a refinery to the current industrial complex operations commenced.

- At the time of this report, the facility is undergoing major redevelopment in association with shale gas related projects and other infrastructure changes.

- Historically, AOI 5 contained the 15 Plant units, a portion of the 17 Plant units, the Lower No. 1 Tank Farm (Ship Unloading Section), storm water tankage, and the Phillips Island area. The majority of the 15 and 17 Plant units were decommissioned and demolished in 2015 and 2016. Many of the storage tanks in AOI 5 have been closed in recent years. Several capital development projects either have been completed or are currently underway within AOI 5.

- The Phillips Island Act 2 Site located in the southernmost portion of AOI 5 has previously been closed through the Act 2 process. A Final Report was submitted in September 2005 (URS, 2005), and a Release of Liability Under Act 2 was granted for this portion of the former refinery (Phillips Island Act 2 Site). The area of AOI 5 located within the Phillips Island Act 2 Site, as defined by the Final Report, is excluded from the scope of this RIR. Florida Power and Light completed the construction of a 744-megawatt combined-cycle, co-generation, and natural gas-fired power plant in this area in 2004. In 2016, the power plant was purchased by Starwood Energy Group and is now referred to as the Marcus Hook Energy Center.

10.2 GEOLOGY

- The Marcus Hook Industrial Complex occurs within the up-dip edge of the Coastal Plain Physiographic Province, approximately one and a half miles southwest of the edge of the Piedmont. The Coastal Plain is defined as having relatively flat topography and as being underlain by a wedge of unconsolidated sediments that thicken in a southeasterly direction atop a sloping bedrock surface. Topography at the facility slopes to the southeast toward the Delaware River.

- As described in **Section 2.2**, Stantec has grouped and generalized some of the observed complexity in the geologic framework underlying the facility to describe three general deposits: anthropogenic fill, a combination of Holocene-age and Pleistocene-age alluvium consisting primarily of muddy and organic-rich sediments, and a lowermost unit comprised of Pleistocene-age alluvium that is predominantly granular in nature.

- Bedrock beneath the facility has been identified to be the Ardentown Granitic Suite of the Arden Plutonic Supersuite which includes quartz norite, quartz monzonorite, opdalite, and charnockite. More recent geologic mapping (Bosbyshell, 2005) suggests that a newly identified bedrock geologic unit, the Ordovician-age Chester Park Gneiss, may be present beneath Coastal Plain sediments.

10.3 HYDROGEOLOGY

- Groundwater occurs in the unconsolidated sediments overlying bedrock at the facility. The aquifer consists of the saturated portions of the fill, muddy alluvium, and granular alluvium.

- Due to the highly variable nature of the composition of the unconfined aquifer, hydraulic conductivity values are expected to also be highly variable. When transport calculations are made using hydraulic conductivity values, a conservative value 328.1 ft/d representing gravel was selected.

- The average hydraulic gradient across the facility is 0.007 ft/ft, and groundwater flow is generally towards the southeast in the direction of the Delaware River. However, some local variability in hydraulic gradient and groundwater flow direction is noted. The groundwater flow pattern appears to be affected by topography associated with former Linwood Creek in AOIs 5 and 2, and by the relocated Middle Creek along its exposed portion in AOIs 5 and 7, where there is potential for groundwater discharge to surface water. Along the eastern boundary of AOI 5, groundwater flow direction is indicated to be east towards the former Linwood Creek, and along the southern AOI 5 boundary some degree of groundwater convergence is apparent along that same feature.

- Bedrock underlying the facility is comprised of a medium to coarse grained crystalline member of the Ardentown Granitic Suite. Crystalline rocks generally have no porosity with little, if any, secondary porosity which results in low hydraulic conductivities.

10.4 COMPOUNDS OF CONCERN

10.4.1 Soil

- Soil investigations performed for the remedial investigation targeted potential source areas including open storage tank incident areas, historical releases, product handling and storage locations, and RCRA SWMUs and AOCs. Available historical data were used in the remedial investigation dataset.

- Delineation was performed to the higher of NRDC MSC and the lead SSS, as concentrations of COCs exceeding these values would require a remedial measure in order to attain a standard under Act 2. Samples were analyzed for the Evergreen Petroleum Short List or the Evergreen Comprehensive List as was deemed appropriate for each potential source area. Some areas also included RCRA metals as COCs.

- The following COCs were detected above the NRDC MSC:

  - benzene (MH-617-5, MH-618-2, MH-618-7)
  - ethylbenzene (MH8-4, MH8-5, MH8-8, MH8-16, MH8-25)
  - 1,2,4-TMB (MH8-16)
  - toluene (MH615-1, MH-617-5)
  - xylenes (MH8-8, MH8-16, MH614-3C, MH 614-6)
  - benzo(a)pyrene (MH11 SS-10, MH8-10, MH8-11, MH8-26)
  - arsenic (AOI7-BH-16-010, AOI7-BH-16-011)
  - cadmium (AOI5-BH-16-037, AOI7-BH-16-010)
  - chromium (MHIC-388-4, AOI5_BH-15-11, AOI5_BH-15-12, AOI5-3, AOI5-4, AOI5-5, AOI5-BH-16-044)
  - lead (AOI7-BH-16-010, AOI7-BH-16-011)
  - vanadium (AOI-5-BH-15-5, AOI-5-BH-15-7, AOI-5-BH-15-10, AOI5-BH-16-073)

- Where identified in surface soil to exceed the referenced standards, benzene, ethylbenzene, 1,2,4-TMB, toluene, xylenes, benzo(a)pyrene, arsenic, cadmium, chromium, lead and vanadium have been delineated both horizontally and vertically through characterization activities and review of existing soil sample analytical data.

- The seven exceedances for chromium listed represent total chromium concentrations compared to the more conservative hexavalent chromium NRDC MSC. To evaluate the proportion of hexavalent and trivalent chromium, samples were collected for analysis of trivalent chromium, hexavalent chromium and total chromium in locations of previous exceedances, where accessible. These additional speciation samples were collected from locations near the SWF at AOI5-3 (AOI5-BH-16-085), AOI5-4 (AOI5-BH-16-084), and AOI5-BH-16-044 (AOI5-BH-16-086). Samples were also collected from AOI5-BH-16-082 and AOI5-BH-16-083 for delineation purposes. In these cases, a maximum of 1.5% of the total chromium concentration was hexavalent chromium. Three of the chromium exceedances were located with the former Tank 388 dike (AOI5_BH-15-11, AOI5_BH-15-12, and MHIC-388-4). The immediate area was not accessible during RI activities due to construction; therefore, delineation samples were collected outside of the former tank dike and analyzed for hexavalent and trivalent chromium in addition to total chromium (AOI5-BH-17-01 through AOI5-BH-17-04). Hexavalent chromium comprised a maximum of 7.1% of the total chromium concentrations in these samples. In light of these results, Evergreen concludes that it is likely that total chromium concentrations represent primarily trivalent chromium concentrations.

- There are two areas in AOI 5 that have elevated vanadium concentrations, the former 15 Plant Boiler House (AOI-5-BH-15-5, AOI-5-BH-15-7, and AOI-5-BH-15-10) and near the SWF (AOI5-BH-16-073). These areas of vanadium NRDC exceedances do not correspond to elevated concentrations of hydrocarbons in soil. However, 15 Plant is a former operational area and there was historic release from Tank 4 in the area of the SWF. Evergreen cannot definitively determine whether vanadium was released in these areas. PADEP has suggested the use of the composite worker EPA RSL HQ=0.1 of 580 mg/kg as a reasonable screening tool for evaluating the risk posed to workers from exposure to vanadium in soils at the facility. The concentration at AOI5-BH-16-073 is below this screening value, but those at the former 15 Plant Boiler House are not. Additional evaluation of areas exhibiting elevated vanadium concentrations is necessary as this compound can be naturally occurring and release of liability under Act 2 may be granted only for released substances.

10.4.2 Groundwater

- In general, non-LNAPL bearing wells were sampled at least twice between 2013 and 2017 as part of the remedial investigation. Groundwater samples were analyzed for the Evergreen Petroleum Short List or the Evergreen Comprehensive List as was deemed appropriate for each potential source area. Some monitoring wells also included RCRA metals as COCs.

- Concentrations of the following COCs were detected above the SHS during the characterization groundwater sampling events in AOI 5: 1,2,4-TMB, EDB, EDC, 2-methylnaphthalene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenz(a,h)anthracene, ethylbenzene, indeno(1,2,3-c,d)pyrene, lead, MTBE, naphthalene, and vanadium. In addition to lead, arsenic was the only RCRA metal with SHS exceedances in AOI 5 groundwater.

10.4.3 Indoor and Ambient Air

- Indoor and outdoor air sampling events were conducted in the heating season (fall/winter months) when levels of VOCs inside buildings are expected to be higher than during warmer months (spring/summer months).

- Detected concentrations of VOCs in indoor and ambient air were below the EPA RSLs.

- Offsite exposure to COCs via vapor intrusion is potentially a pathway of concern. Benzene was detected above the SVGW-NR near the Pennsylvania-Delaware boundary in MW-581 in recent years. The vapor intrusion pathway for offsite receptors, including potential migration along preferential pathways, will be assessed further in a future Act 2 deliverable.

10.5 LNAPL DISTRIBUTION AND MOBILITY

- A comprehensive LNAPL Conceptual Site Model (LCSM) was prepared for AOI 5, which includes gauging data from AOIs 1 through 4, and is included as **Appendix G** of this RIR.

- LNAPL samples collected from site monitoring wells through time have identified the presence of several variably-weathered products and mixtures of products refined from crude oil in the subsurface (**Figure 5-1**).

- Variability in LNAPL characteristics observed is indicative of multiple product releases at different times with subsequent co-mingling of plumes. With a few exceptions, areas of LNAPL are identified and delineated within AOI 5.

- A review of apparent LNAPL thickness and distribution data through time suggests that overall, LNAPL plumes in AOI 5 are not migrating. In general, the vertical thickness of LNAPL as observed in monitoring wells has not been increasing and has not been identified in downgradient portions of the monitoring well network that have historically lacked measureable LNAPL.

- However, additional metrics presented in the LCSM indicate that areas of potentially mobile and practicably recoverable LNAPL are still present at several areas that are distal to, or at the leading edge of, active remediation systems.

- Observed LNAPL appears to be stable or decreasing (not migrating) and immobile at most locations along the plume fronts presented. LNAPL areas are continually monitored through routine well gauging. LNAPL is not observed offsite and delineation of LNAPL is achieved in AOIs 1 through 5 by monitoring wells that have no observed or measurable LNAPL.

10.6 QUALITATIVE FATE AND TRANSPORT

- A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport assessment presented in this RIR. Rather, a qualitative-level assessment of groundwater data has been completed.

- As the groundwater investigation in AOI 5 covered a large area and numerous COCs have been detected in exceedance of the SHS throughout the AOIs, areal occurrence of exceedances was examined to select COCs that could be used as qualitative-level proxies. These compounds were selected for a variety of reasons including high water solubility, greatest areal extent of impact, and representativeness of areal extent/concentration values. Compounds selected to represent all COCs in groundwater were benzene, MTBE, 1,2,4-TMB, benzo(a)pyrene, chrysene, bis(2-ethlyhexyl) phthalate, naphthalene, arsenic, lead, and vanadium.

- Plume distributions are discussed in detail in **Section 8.7**. Dissolved phase VOCs plumes correlate with areas of historical product handling and storage in the Lower No. 1 Tank Farm, 15 Plant area, 17 Plant Area, and southern AOI 5 near Middle Creek towards Phillips Island. Elevated arsenic concentrations within AOI 5 are observed south of Middle Creek. The RCRA Facility Investigation (RFI) for AOI 7 (GHD, 2017b) described arsenic impacts in surface water and sediment related to the adjacent Delaware Valley Works (DVW) property located to the southwest of AOI 7 in Delaware. Lead and vanadium are present at concentrations above the SHS near the Pennsylvania-Delaware boundary in an area between the former 15/17 Plants and the current Middle Creek vicinity. Discrete plumes of these two metals are also present in areas of the Lower No. 1 Tank Farm.

- With some exceptions, which will be subsequently described, current concentrations of COCs are delineated to the SHS within the MHIC property boundary. RIR data does not support that concentrations in groundwater of benzene, 124-TMB, arsenic, lead, and vanadium are delineated within AOI 5 at its western boundary.

- Perimeter groundwater monitoring has been conducted at the MHIC since the mid-1990s. An evaluation of these results, as described in **Section 8.8**, shows decreasing trends over time for COCs where COCs were detected above reporting limits.

10.7 EXPOSURE PATHWAY AND RECEPTOR EVALUATION

For a pathway to be considered complete, it must have a source, a transport medium, a receptor, and an exposure route. The following section examines exposure pathways by media to identify which routes are potentially complete. The exposure routes of concern that will be evaluated are ingestion, dermal exposure, and inhalation. Onsite workers and the public will be evaluated as receptors. As discussed in **Section 9.0**, additional evaluation of potential ecological receptors will be conducted.

10.7.1 Soil

- Access to AOI 5 is restricted by fencing and security measures implemented by SPMT. This would preclude the public from potential onsite exposures to soil.

- The soil-to-groundwater pathway is evaluated through the groundwater investigation and analysis documented in this RIR.

- SPMT is responsible for oversight of contractor safety, and requires personal protective equipment (PPE) and work plan/permitting protocols that mitigate the potential for worker exposure to impacted soil through the direct contact and inhalation exposure pathway. These administrative controls which are implemented through established safety standards for the facility include requirements for workers to wear proper PPE and perform air monitoring when conducting activities that include disturbance of soils (i.e. excavation). Therefore, exposure to surface soils (0-2 ft bgs) as the only current potentially complete pathway for dermal exposure to soils by workers. Locations of soils containing concentrations of COCs exceeding the NRDC MSC, as listed in **Section 10.4.1**, have been delineated, and strategies to remediate these exceedances will be presented in the Cleanup Plan. Additionally, for compounds for which the subsurface NRDC MSC is driven by the inhalation pathway, controls established in the safety standards are not sufficient to eliminate potential exposures. Strategies to remediate subsurface exceedances for these compounds will also be presented in the Cleanup Plan.

- Volatilization to indoor air was investigated for occupied buildings onsite. This pathway was evaluated through the collection of indoor air samples as described in **Section 6.1**. Concentrations of volatile COCs were compared to the EPA RSLs, TR=1E-5, THQ=0.1, as it is anticipated that following remedial measures, volatilization to indoor air will be the only remaining potentially complete pathway. No COC concentrations were detected above the EPA RSLs.

- Volatilization from soil to outdoor air was investigated in an area of NRDC MSC exceedances for VOCs. No COC concentrations were detected above the EPA RSLs in this sample.

10.7.2 Groundwater

- As described in **Section 10.7.1**, volatilization to indoor air was evaluated for occupied buildings onsite. No COC concentrations were detected above the EPA RSLs in indoor air samples.

- Due to the potential for offsite transport of COCs via groundwater flow, the volatilization to indoor air pathway was also evaluated for this medium. Concentrations of VOCs at the Pennsylvania-Delaware boundary were screened against the SVGW-NR. Currently, the only SVGW-NR exceedance is for benzene at MW-581.

- A well search (**Appendix K**) was conducted using the PaGWIS and a FIOA request to DNREC. The search was completed for an area inclusive of approximately 1.0 miles from the facility property boundary in each direction. The search did not identify any potable production wells located downgradient of the facility. Additionally, Marcus Hook Borough and Lower Chichester Township are developed municipalities with established public water service.

- Due to the location of the site along the Delaware River, there is potential for dissolved phase COCs to migrate into surface water. Under 25 PA Code §93.9g, potable water supply is not a protected use of the tidal portions of the Delaware River estuary; therefore, the water ingestion exposure pathway is incomplete. However, exposure of fish and aquatic life and human consumption of fish are pathways of concern. This pathway will be further evaluated in future Act deliverables using CORMIX modeling to back-calculate groundwater screening values from human fish of consumption criteria and 25 PA Code Chapter 93 (Chapter 93) fish and aquatic life standards.

- As described in **Section 10.7.1**, SPMT is responsible for oversight of contractor safety, and implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to impacted groundwater through the direct contact and inhalation exposure pathways. Worker contact with groundwater would be eliminated through the implementation of these institutional controls.

10.7.3 LNAPL

- As described in **Section 10.7.1**, volatilization to indoor air was evaluated for occupied buildings onsite. No COC concentrations were detected above the EPA RSLs in indoor air samples.

- Potential volatilization to outdoor air was investigated in LNAPL areas. No COC concentrations were detected above the EPA RSLs in outdoor air samples.

- As described in **Section 10.7.1**, SPMT is responsible for oversight of contractor safety, and implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to LNAPL through the direct contact and inhalation exposure pathways. Worker contact with LNAPL would be eliminated through the implementation of these institutional controls.

- Occurrences of LNAPL within AOI 5 have been delineated to the MHIC property; therefore, offsite exposure to LNAPL is not of concern.

11.0 COMMUNITY RELATIONS ACTIVITIES

A Community Relations Plan (CRP) that includes public involvement with local residents to inform them of the anticipated investigations and remediation activities was included in the Work Plan. The purpose of the CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens to be informed of onsite activities related to the investigation activities at the MHIC. This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action Program. This report and future Act 2 reports will include the appropriate municipal and public notices in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Evergreen intends to hold public meetings as necessary in the Borough of Marcus Hook to present the strategy and give status updates of the project.

12.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Stantec has prepared this RIR for AOI 5 of the Marcus Hook Industrial Complex to satisfy the requirements under Act 2, as specified under 25 PA Code §250.408 (Remedial Investigation Report). The documented investigation activities were performed in general accordance the Work Plan, and a subsequent collaborative work scope meeting with PADEP. The characterization investigations were conducted in support of Evergreen's commitment to remediate legacy environmental impacts that existed at the facility prior to Sunoco, Inc. (R&M)'s transfer to SPMT in 2013. In support of those stated objectives, this report has described a comprehensive evaluation of available historical data pertaining to AOI 5, and has documented a remedial investigation strategy that included the collection of a significant amount of subsurface information and analytical data.

The following summarizes the conclusions and recommendations regarding characterization of AOI 5.

12.1 SOIL

Benzene, ethylbenzene, 1,2,4-TMB, toluene, xylenes, benzo(a)pyrene, arsenic, cadmium, chromium, lead, and vanadium were identified in soil at concentrations exceeding the NRDC MSC. Where identified in soil to exceed the NRDC MSC, these compounds have been delineated horizontally and vertically. The VOC and SVOC exceedances are from soil samples collected during storage tank CAP program investigations that are either closed (Tank 11) or for post-2013 incidents (Tanks 613 through 619 and Tank 8). The exceedances for the post-2013 incidents will continue to be addressed through the CAP program.

An evaluation of the proportions of hexavalent and trivalent chromium at the site has lead Evergreen to conclude that total chromium concentrations detected represent primarily trivalent chromium. Therefore, remedial action is not necessary to address instances in which total chromium has been detected above the hexavalent chromium NRDC MSC.

For areas exhibiting concentrations of vanadium above the NRDC MSC, results were compared to the composite worker EPA RSL HQ=0.1 of 580 mg/kg. Soil from locations exceeding this EPA RSL (AOI-5-BH-15-5, AOI-5-BH-15-7, and AOI-5-BH-15-10) will require further pathway evaluation or a remedial measure to attain a standard under Act 2.

The remaining metals exceedances for lead, cadmium, and arsenic (AOI5-BH-16-037, AOI7-BH-16-010, and AOI7-BH-16-011) will also require further pathway evaluation or a remedial measure to attain a standard under Act 2. Strategies to remediate these exceedances will be presented in the Cleanup Plan.

12.2 GROUNDWATER

1,2,4-TMB, EDB, EDC, 2-methylnaphthalene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenz(a,h)anthracene, ethylbenzene, indeno(1,2,3-c,d)pyrene, lead, MTBE, naphthalene, and vanadium were identified onsite at concentrations in excess of the SHS during characterization sampling activities conducted in AOI 5. With some exceptions, current concentrations of COCs are delineated to the SHS within the MHIC property boundary. RIR data does not support that concentrations in groundwater of benzene, 1,2,4-TMB, arsenic, lead, and vanadium are delineated within AOI 5 at its western boundary. AOI 5 and AOI 7 are separated by the Pennsylvania-Delaware state boundary. Evergreen and EPA are currently working under a CAF in the RCRA First Program to address environmental impacts present within the AOI 7 portion of the facility which is located in Delaware

There is a long history of groundwater monitoring at the property boundary that shows decreasing trends of COC concentrations (where they have been detected). A future Act 2 deliverable will include quantitative groundwater modeling to further evaluate the fate and transport of contaminants at the site. This groundwater modeling, along with CORMIX modeling will be used to further examine the potential for dissolved phase COCs to migrate to the Delaware River and evaluate a potentially complete exposure pathway via human consumption of fish.

A complete exposure pathway also may exist for ecological receptors. Evergreen plans to use the Chapter 93 fish and aquatic life standards to evaluate potential exposures in the Delaware River. Additionally, since initial screening has indicated that threatened and endangered species are present in proximity to the site, an ecological risk assessment will be conducted.

It is expected that the selected remediation standard for dissolved phase COCs in groundwater which exceed the SHS will be the SSS via pathway elimination. The SHS may be selected for groundwater COCs which meet or are below the SHS at the points of compliance.

12.3 VAPOR INTRUSION PATHWAY

Concentrations of COCs in indoor and ambient air were evaluated for occupied onsite buildings in AOI 5. Observed COC concentrations were below the applicable screening values in the building and ambient air samples. It is noted that the use of this screening value is dependent upon the remainder of the exposure pathways being eliminated through other remedial activities and controls, as this is a condition of the use of the EPA RSL TR=1E-5, THQ=0.1.

To confirm concentrations of COCs detected during the first round of indoor air sampling conducted in February 2017, it is anticipated that a second sampling event will be conducted in the occupied buildings located in AOI 5 with results being presented in future Act 2 deliverables.

Infiltration of groundwater into underground utilities has the potential to generate vapors along subsurface corridors. Evergreen has not identified these types of preferential pathways within AOI 5 specifically. However, this is a known pathway in adjacent AOIs, and options to address these potential preferential pathways will be addressed in the Cleanup Plan.

Due to the potential for offsite transport of COCs via groundwater flow, the volatilization to indoor air pathway was also evaluated for this medium. Concentrations of VOCs at the Pennsylvania-Delaware boundary were screened against the SVGW-NR. Current concentrations of benzene at MW-581 exceed the SVGW-NR. Impacts from the facility that are present in Delaware will be addressed under the CAF and RCRA First Program.

12.4 LNAPL

LNAPL present in the subsurface at and directly adjacent to AOI 5 has been delineated into general plume areas as depicted on **Figure 5-1**. The results of LNAPL sampling have characterized the LNAPL plumes into general categories including light distillates, middle distillates, and heavy distillates. The LNAPL characterization results are indicative of multiple product releases at different times (**Appendix G**).

Data evaluated in this RIR indicates that the majority of LNAPL in AOI 5 is generally not migrating or practicably recoverable. However, LNAPL present at several areas that are distal to active remediation systems, may be mobile, able to migrate, and recoverable. These areas include the eastern edge of the Phillips Island Remediation System plume area, 17 Plant Tankage area in the vicinity of MW-468, and Lower No. 1 Tank Farm area in the vicinity of MW-83. Active LNAPL recovery system operation and well monitoring in AOI 5 in the Middle Creek and Phillips Island areas are ongoing to mitigate and monitor for the potential migration of LNAPL. The LNAPL plumes identified within AOI 5 are delineated to the property boundary by onsite wells that are absent of LNAPL.

Opportunities are available for refinement of the LCSM and expansion of LNAPL recovery systems to address the potentially recoverable LNAPL (and dissolved phase contaminants) identified in AOI 5. Further consideration of LCSM refinement and LNAPL recovery options will be addressed as part of Cleanup Plan activities.

13.0 SIGNATURES

The following parties are participating in the remediation at this time and are seeking relief of liability under Act 2 of 1995.

Tiffani L. Doerr, P.G.
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This RIR has been prepared in accordance with the final provisions of Act 2 and the June 8, 2002 Land Recycling Program Technical Guidance Manual.

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